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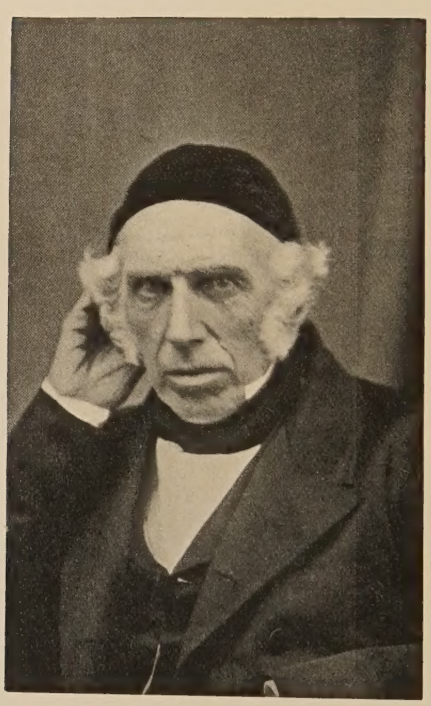

Very truly yours
Joshua Alden

THE
BRITISH TUNICATA

AN UNFINISHED MONOGRAPH

BY THE LATE
JOSHUA ALDER

AND THE LATE
ALBANY HANCOCK, F.L.S.

EDITED BY
JOHN HOPKINSON, F.L.S., F.G.S., ETC.
Secretary of the Ray Society

WITH A HISTORY OF THE WORK BY THE
REV. A. M. NORMAN, M.A., D.C.L., F.R.S., ETC.
Honorary Canon of Durham

VOLUME I

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V. 1

THE HISTORY OF THIS WORK.

At a date between 1855 and 1860, Mr. Joshua Alder, at the request of Dr. J. E. Gray, Keeper of the Zoological Department of the British Museum, undertook to prepare a 'Catalogue of British Tunicata.' This Catalogue was to be published by the British Museum as one of a series of works which included Busk on the 'British Polyzoa,' Spence Bate on the 'Crustacea Amphipoda,' and George Johnston on 'British Nonparasitic Worms.' Alder at once gave his whole time to the preparation of this volume. In 1863 the work was done, the whole of the descriptive portion neatly written out and ready for the printer, while the Plates, which gave coloured illustrations of the then known species, together with drawings of portions of the branchial sac of many of the forms, were completely finished, and only required engraving. When, however, Alder wrote to Dr. Gray to inform him that this was the case, he received a letter in reply which expressed the deepest regret that the Trustees (or the Government ?) had withdrawn the grant for the publication of these Catalogues, and that therefore, unfortunately, he was unable to avail himself of Alder's valuable work.*

* The last of these Catalogues, that of Dr. Johnston, was not published until 1865, but, as noted in the Preface, "the publication had been delayed owing to the lamented death of Dr. Johnston," after which it was completed by Dr. Baird.

It now became necessary to consider what steps should be taken to carry out the publication of Alder's work; and he naturally consulted his old friend and colleague Mr. Albany Hancock. It was then agreed between them that a more elaborate monograph should be undertaken, in the carrying out of which Hancock should join him and work out the Anatomy and Physiology of the Class in a similar manner as he had done in the joint great work on the 'Nudibranchiate Mollusca,' and that the monograph should be offered to the Ray Society. That Society was only too glad to have the opportunity of procuring another work from such authorities. Hancock, many years before, had paid some attention to the subject, and in Alder's "Catalogue of the Mollusca of Northumberland and Durham" the portion relating to the Tunicata was under the names of Alder and Hancock.*

Hancock immediately put aside the investigations he at that time was engaged in on the Anatomy of the Cephalopoda, and devoted the rest of his life, so far as health would permit, to unceasing labour on the elucidation of the structure of the Tunicata. The following extracts from the Minute Book of the Ray Society, printed by permission of the Council, will show how matters progressed, and how the extent of the labour involved became increasingly evident.

Ray Society—Council Meetings.

1863, Oct. 2.—Read a letter from Mr. Alder offering a work by himself in conjunction with Mr. Albany Hancock on the British Tunicata. Resolved to accept this offer.

1863, Nov. 6.—Read a letter from Mr. Alder stating that for the proposed work on the British Tunicata about twenty

* Joshua Alder, "A Catalogue of the Mollusca of Northumberland and Durham" (1848), 'Trans. Tyneside Nat. Field Club,' vol. i, pp. 97–207.

plates would be required, two-thirds of which would have to be coloured either wholly or in part, and that the letterpress would not exceed one hundred pages quarto.

1865, Sept. 1.—Read a letter from Mr. Alder stating that Mr. Hancock expected to complete his investigations of the Anatomy of the Tunicata at the end of this year, and that they hoped that they should have the Monograph ready for the press by the end of the year 1866.

1866, June 1.—Read a letter from Mr. Joshua Alder stating that the progress of the work on the Tunicata had been much impeded by the serious illness of Mr. Hancock, and begging that it might not be announced as one of the volumes for 1867.

1867, Feb. 1.—The Secretary reported the death of Mr. Joshua Alder on the 21st of January. Resolved that the Secretary communicate with Mr. Albany Hancock to ascertain the degree of forwardness of the proposed work on the British Tunicata.

1867, April 12.—Read a letter from Mr. Albany Hancock stating that there yet remained very much work to be done in connection with the proposed work on the British Tunicata; but that so soon as his health would permit he should consider it a duty he owed to the memory of his late friend to do his best to prevent the labours of his latter years from being lost to science.

Sad for the survivor was the break in the lifelong friendship of these two admirable naturalists, when death called away Hancock's colleague, Joshua Alder, on the 21st of January, 1867, in his seventy-fifth year. Hancock was now more than ever anxious that the monograph should be completed in the contemplated manner, and he laboured at his investigations as steadily as enfeebled health would permit. In the following year he published, as a first result of his studies, a paper in the 'Journal of the Linnean Society,' vol. ix, "*On the Anatomy and Physiology of*

the Tunicata." This paper makes known to us his views up to that date. The proper introduction to the present work was never written, and it is obvious that it would have been the last thing done, so that it might embrace the writer's final views subsequent to the completion of his dissections of the entire class. In the absence of such an introduction it has been deemed advisable to reprint the paper from the Journ. Linn. Soc. just referred to. In the autumn of 1873 Hancock had "completed about two-thirds and a portion of the remainder" of his work, and "was within two years of the time when he expected to be able to bring it to a conclusion."* But now his final sickness attacked him, and dropsical symptoms supervening he died on the 24th of October, 1873.

The question which the closest friends of the authors asked themselves was, What was now to be done? After much consultation, but not until August, 1875, it was agreed that if Professor Huxley could be induced to take up this matter, write an introduction, and advise generally as to preparing the work for the press, all would be well. A meeting, therefore, was arranged. Sir William (afterwards Lord) Armstrong invited Professor Huxley to stay with him for two nights at Cragside, Rothbury, and also the following naturalists and friends of the authors to meet him:—Mr. John Hancock (the Ornithologist, and brother of Albany), Dr. Embleton (joint author with A. Hancock in some of his anatomical work,† his medical adviser, and a very close friend to the last), and the Rev. A. M. Norman.

* Dr. Embleton's "Life of Albany Hancock," 'Nat. Hist. Trans. Northumberland and Durham,' vol. v (1874), p. 132.

† A. Hancock and Dennis Embleton, "On the Anatomy of Eolis," 'Ann. and Mag. Nat. Hist.,' Vol. XV (1845), p. 1, pls. i–v; Ser. 2, Vol. I (1848), p. 88, pls. iii, iv; Ser. 2, Vol. III (1849), p. 183, pl. v; and "On the Anatomy of Doris," 'Philos. Trans.,' 1852, pp. 207–252, pls. xi—xviii.

After the matter had been fully gone into, and the MSS. and drawings had been examined, Professor Huxley expressed his willingness to do what he could in the matter, but said he should require some fresh specimens of *Ascidia mentula* for dissection. These Mr. Norman undertook to procure for him, and this was done through the kind help of Mr. David Robertson, of Cumbrae, who went specially to Oban to obtain the specimens, which he sent to Huxley.*

When a little more than four years had passed, the letter here given was received from Professor Huxley by Dr. Embleton.

"4, Marlborough Place,
"London, *October 12th*, 1879.

"My dear Sir,

"After my return from Newcastle, I forget how many years ago, I examined Albany Hancock's MSS. and drawings more carefully than I had before been able to do, and I confess that the work of making a presentable volume out of them did not appear to me to promise to be easy, but I was quite prepared to do my best. However, shortly afterwards, in talking over the matter with a Member of the Council of the Ray Society, he assured me that there was not the least chance of the Society undertaking the publication for two years from that date, and from that and various other circumstances, I felt inclined to doubt whether a still longer time might not elapse before the Society would be in a position to undertake so expensive a work.

"Under these circumstances, I put the papers carefully on one side and waited for events. But, of course, my other occupations went on, and I am not at all sure that if the Ray Society offered to publish the work at once I could give the time (not so much for the editing and writing of the Introduction, as for the supervision of the execution of the Plates) that would be requisite.

* See 'The Naturalist of Cumbrae, being the Life of David Robertson' (1891), by the Rev. T. R. R. Stebbing, pp. 304–305.

"But it is a thousand pities that the work remains unpublished, and if anything can be done, the MSS., so far as I am concerned, are absolutely at the disposal of Hancock's representatives. I shall be obliged if you will kindly communicate the substance of what I have said.

"With my regards to Mr. John Hancock,

"I am, yours very truly,

"T. H. Huxley."

Shortly after this the MSS. and drawings were returned. These, after the deaths of Mr. John Hancock and Dr. Embleton, were placed under the care of the Committee of the Natural History Society of Newcastle-upon-Tyne, where they have remained until last year, when, the work having again been accepted by the Council of the Ray Society, they were at my request sent for publication at last by this Society.

Though so many years have elapsed, the value of the Monograph is great, since (1st) it contains full descriptions with illustrations of the Tunicata of our fauna as known up to the time of the death of the authors; (2nd) because many of the new species had been only briefly diagnosed, and the fuller descriptions and figures of these which are now given will enable them to be better known and understood; and (3rd) it is especially desirable that the full account of Hancock's investigations should be published together with a portion of his beautiful drawings.

The chief difficulty from the first has been in relation to these drawings, which are extremely numerous. All Hancock's admirable work was effected with the aid of such simple means as scalpels and needles. Section-cutting and the use of chemical reagents were in his day unknown. Our author's custom was to gradually and most carefully dissect the animal, and to continually make new drawings as each fresh mem-

brane or organ was removed, thus mastering every detail, and then, aided by the numerous sketches before him, the finished drawing was produced. Now among the mass of drawings relating to the Tunicata, comparatively few have been finally perfected. These have been here reproduced, together with such careful selections from the rest of the drawings as seemed to possess most value.

A large amount of work has been undertaken by Mr. John Hopkinson, the Secretary of the Society, in the preparation of the Monograph for the press. With much labour he has filled up the blanks which had been left in the bibliographical history, and done a great deal in the elaboration of references, and the verification of various details. The result of some of his work will be recognised by the circumstance that all numbers, words, and passages which he has supplied are enclosed in brackets in order to indicate that they were not in the MSS. of the authors. In addition to all this Mr. Hopkinson has arranged on the plates and in the text all the drawings selected for publication, and when necessary deepened the outlines, etc., in order that they might come out more satisfactorily in the photographs.

It may be well, in conclusion, to make some remarks on the MS. and the figures of the species. The MS., as received from Newcastle, was a transcript which had been made by Mr. Joseph Wright, of the Museum there, for more ready use by Professor Huxley. The original MSS. would appear to have been since mislaid. The transcript has been carefully made, and the portions which had been in the handwritings of Alder and Hancock respectively have been scrupulously indicated. In the account of the species the diagnostic characters

with which the notice begins were in all cases up to the time of his death written by Alder, as also for the most part were the sentences which draw attention to the chief distinguishing features, and affinities with allied species.

Most of the coloured figures of the species have been taken from the Plates which Alder had prepared for his Catalogue. Unfortunately there was no description of these plates forthcoming, and the identification of a few of the figures has been attended with some difficulty. There were also later drawings by him of new species discovered up to the time of his death; and a few additional illustrations of varieties have been given from some of Alder's drawings in my possession. These were found in the portfolios which contained all his natural history drawings (except the Tunicata), which were most kindly given to me by Miss Alder after the death of her brother.

A. M. NORMAN.

Berkhamsted,
27*th March*, 1905.

NOTE ON THE ILLUSTRATIONS.

With the exception of figs. 5 and 6 in the text, which have been re-drawn, all the illustrations in this volume are photographic reproductions of original drawings by the authors—the coloured plates and the illustrations in the text, by the half-tone process; the uncoloured plates (the frontispiece excepted), by collotype.

The Editor has arranged the figures on the plates and in the text, and has strengthened the outlines and more important details which were too faint for the camera. In all other respects the figures are exact reproductions of the authors' drawings, a result only attainable by photography. Owing, however, to the paper on which some of the figures in the collotype plates were drawn having changed colour with age, the ground is in some cases too dark, and in Plates XVII and XVIII is not uniform in shade.

Plates I, V, VII, XI, XV, and XVI are from drawings by Mr. Alder, and the figures are of the same size as drawn by him. The rest, and all the text illustrations, are from drawings by Mr. Hancock, and nearly all these are reduced in size in various proportions.

JOHN HOPKINSON.

Weetwood, Watford,
27*th March*, 1905.

LIST OF THE PLATES.

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I.—*Ascidia mamillata.*

II.—*Ascidia mentula.*

III.— „ „ details.

IV.—Figs. 1, 2.—*Ascidia rubicunda.* Figs. 3, 4.—*A. Normani.*

V.—*Ascidia mollis.*

VI.—*Ascidia plana:* blood-channels in mantle.

VII.—Figs. 1–4.—*Ascidia rudis.* Fig. 5.—*A. venosa.* Figs. 6–8.—*A. depressa.* Figs. 9–11.—*A. aculeata.*

VIII.—*Ascidia venosa:* blood-channels in test.

IX.— „ „

X.— „ „ branchial sac.

XI.—Figs. 1, 2.—*Ascidia amœna.* Figs. 3–5.—*A. plebeia.* Figs. 6, 7.—*A. sordida.* Figs. 8, 9.—Probably a variety of *Corella parallelogramma.* Fig. 10.—*Ascidia obliqua.*

XII.—*Ascidia sordida.*

XIII.— „ „ reproduction.

XIV.—*Ascidia Morei.*

XV.—Figs. 1–7.—*Ascidia scabra.* Figs. 8, 9.—*A affinis.*

XVI.—Figs. 1–3.—*Ascidia pustulosa.* Figs. 4–7.—*A. elliptica.* Figs. 8, 9.—*A. pellucida.*

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BRITISH TUNICATA.

INTRODUCTION.*

Notwithstanding the great amount of labour which has been bestowed on the investigation of the Tunicata for many years past, these curious and interesting creatures do not yet appear to have found their final resting-place in the classification of the Animal Kingdom. Naturalists are still divided in opinion as to whether the Tunicata, together with the Bryozoa,† should fall into rank at the bottom of the great Molluscan sub-kingdom, whether they form an abnormal group which should be placed in the sub-division Molluscoidea of Milne-Edwards, or whether it is desirable to unite the Brachiopoda with them.

Our recent researches, however, have forced upon us the conclusion that the subjects of this monograph are indeed true Mollusca closely related to the Lamellibranchiata—much more closely than they are to either the Bryozoa or the Brachiopoda; and that, whilst the two latter groups may be kept apart in a sub-class or subdivision by themselves, the Tunicata should be placed with the Mollusca.

* Additions to the authors' MS. are placed within brackets in the usual manner, except obviously editorial footnotes. A few verbal corrections have been made which are not so indicated. In the historical portion of the Introduction the original spelling of generic and specific names has been retained.

† This term is here retained in deference to the adoption of it by the authors, although the right of priority rests with Polyzoa. On this point, and also on the intimate relationship existing between the Tunicata and the Polyzoa, see Allman's 'Fresh-water Polyzoa' (*Ray Society*, 1856), and the papers referred to on pages 6 and 43 of that work.

We shall, therefore, consider the Tunicata as the lowest members of the Molluscan series, touching, on the one hand, the Lamellibranchiata, on the other the Bryozoa and the Brachiopoda. They are all marine, shell-less, headless, footless mollusks of a comparatively low organisation, having an elastic external envelope, test, or outer tunic, the homologue of the ordinary molluscan shell, and an internal tunic or mantle; they are provided with a well-differentiated digestive apparatus, usually with a sac-shaped gill placed in front of the digestive organs, and leading to the mouth; with rather well-developed muscular organs, in which the heart is tubular, forcing the blood for a while in one direction, and then reversing its action and forcing it in the opposite direction. They are all androgynous, with very complete reproductive organs, and all undergo a metamorphosis, while the greater number of them increase by buds as well as by ova.

They are mostly attached, apathetic creatures, enjoying locomotion only in their first, or larval, or tadpole state, and being provided with an inhalent and an exhalent tubular orifice, their food, which is composed of microscopic organisms and sedimentary matters, being drawn to the mouth by the respiratory currents. The members of a large tribe, however, are pelagic in their habits, being for ever in action near the surface of the ocean, swimming by the aid of their respiratory currents, which in these instances have the threefold office to perform of aiding in respiration, in nutrition, and in locomotion.

And, finally, the Tunicata are either simple or compound—simple when [each individual is] encased in a separate external envelope, compound when the test, or outer tunic, is fused or expanded so as to include many individuals in one general envelope.

Though the Tunicata have had much attention bestowed on them of late years by the thoughtful naturalist, they have generally been much neglected by, and are but little known to, the casual observer,

partly on account of the unattractive appearance of many of the species, but more so because of the impossibility of making them into pleasing objects for the cabinet, as all colour leaves them when they are placed in spirit. It would be erroneous, however, to suppose that they are devoid of beauty, for many of them must rank among the most charming objects met with in our rock-pools, and some species from the deeper waters rival, in the intensity and purity of their colours, the rich hues of fruits and flowers. Many are splendidly hyaline, others, again, are just transparent enough to reveal the mellow tints of their viscera, producing a rich, lucid appearance. But the most attractive of all are perhaps the stellate *Botrylli*, which spread over stones and fuci in large gelatinous patches of brilliant green, orange, red, and yellow, the colours being intensified in the individuals which are immersed in, and studded over, their investing test in radiating systems.

They are all possessed of the highest interest to the philosophical inquirer on account of their physiological and anatomical peculiarities, as well as for the light which they throw on the structure of their zoological relatives, leading as they do to a fuller comprehension of the organisation of the Lamellibranchiata on the one side, and of the Bryozoa and the Brachiopoda on the other.

The Tunicata are the *Tethyum* of Aristotle.* They were well known to the Father of Natural History, who appears to have justly appreciated their true nature, for he recognised their relationship to the ordinary bivalve Mollusca, and was aware that the test was the homologue of the shell of the higher mollusk.

After his time scarcely anything† is heard of these animals until about the middle of the 16th century,

* [‘Historia Animalium,’ lib. iv, cap. 6; and ‘De Part. Anim.,’ lib. iv, cap. 5. (Cir. B.C. 330.)]

† “Nothing” in the authors’ MS., but see Pliny, ‘Hist. Anim.,’ lib. xxxii, cap. 30, 31, and Ælian, ‘De Nat. Anim.’

when a few species were noticed by several naturalists who confused the subject by placing them with the *Alcyonaria*. It was not until the 12th edition of the 'Systema Naturæ' of Linnæus appeared [i, 2 (1767)] that the simple forms were drawn together under the generic appellation of *Ascidia*, the name *Tethys* being restricted by Linnæus to the animal of the Bivalves. The union of *Tethyum* with the *Ascidium* of Baster ['Opusc. Subsec.,' i (1760)] had already been suggested by Pallas ['Miscel. Zool.' (1766)], and both these naturalists observed the resemblance of these animals to the bivalve Mollusca, as indeed did Linnæus.

Cuvier's first observations on the Tunicata were made in 1797 [in 'Bull. Soc. Philom.']. Then followed, in 1815 [in 'Mém. du Mus.,' ii; see also 'Mém. des Moll.' (1817)], his anatomical researches, which gave a solid, sound foundation as a starting-point for succeeding investigators. This profound anatomist, whose observations were extended to the compound forms, determined the high differentiation of the organism, and proved the close relationship existing between the Tunicata and the Mollusca. But it is erroneous to assert, as some have done, that these justly-celebrated investigations had been carried as far as it was possible to carry them with specimens of Tunicata preserved in spirit. All the organs can be fully determined in simple Ascidians so preserved, not excepting the heart and the vascular apparatus even to its minutest ramifications. What Cuvier did he did well, and he achieved all that was demanded of him by the requirements of science at that time.

Cuvier was also the first to recognise the affinity of the simple and compound Ascidians, but Pallas seems to have suggested this in the few preliminary remarks to his description of the *Botryllus stellatus* of Gærtner ['Spic. Zool.,' fasc. x (1774)]. Cuvier advanced this opinion in the report on Savigny's celebrated "Mémoires" [*Sur les Ascidies composées et les Ascidies simples*] read on the 8th of May following the date of their

presentation to the Institut de France. These memoirs were read at the Institute respectively on the 6th of February and the 1st of May, 1815, and were published in the following year in Savigny's well-known work entitled 'Mémoires sur les Animaux sans Vertèbres.' Together with Cuvier's labours of about the same date, they mark a great epoch in the study of the Tunicata. Savigny's researches separated at once and for ever the compound Ascidians and the Polypes, and enabled Cuvier, from his previously-acquired information, to suggest the intimate relationship existing between the compound and the simple forms, which hence became an accomplished fact.

Lesueur and Desmarest's researches on the compound Ascidians were communicated to the Institute of France in the same year [1815, in 'Bull. Soc. Philom.'].

The 'Histoire naturelle des Animaux sans Vertèbres' of Lamarck was published in the years 1815 to 1822. This philosophical naturalist, having availed himself of the then recent labours of the above distinguished observers, instituted the class Tunicata to embrace the simple and compound Ascidians, the latter including *Salpa*. From a mistaken apprehension of the structure of these animals he separated this class from the Mollusca and placed it between the Radiata and the Vermes; yet in a certain sense he appears to have appreciated the connection which exists between the Ascidians and the Lamellibranchs, for he says that "the series of the inarticulate animals, commencing with the *infusoires*, is continued by the *polypes*, the *tuniciers*, the *acalèphes*, and is terminated by the *mollusques*, of which the last orders are the *céphalopodes* and the *hétéropodes*."

In 1819 Chamisso ['De Anim. Verm.'] gave to the world his startling observations on the reproduction of *Salpa*, in the "alternation of generations," as he at the time termed the phenomenon.* The report of

* [For an account of Chamisso's observations see Steenstrup's 'Alternation of Generations,' translated by George Busk (*Ray Society*, 1845).]

this curious mode of reproduction was received with astonishment, as it was deemed to be unparalleled in the history of animals, although it was well known to the discoverer of *Botryllus* that it was a compound animal which increased by pullulation. Pallas announced this fact on the authority of Gærtner in his 'Spicelegia Zoologica' in 1774. Chamisso's observations were confirmed by Krohn [in 1841].*

In 1821 H. Kuhl and van Hasselt discovered the flux and reflux of the blood in *Salpa*; that curious and characteristic feature in the circulation of the Tunicata, that ebb and flow in the current, first setting for some time in one direction and then flowing in the opposite. Since this peculiar action of the blood-current was made known there has been no lack of subsequent observers who have verified this extraordinary fact in almost every genus in the entire class; and, indeed, there is no difficulty in witnessing the marvellous sight, as no preparation is required; all that has to be done is to place under the microscope a young individual of almost any species so as to secure the necessary transparency, and the phenomenon may be observed for any length of time.

The next important discovery was made by Audouin and Milne-Edwards in 1828 ['Ann. Sci. Nat.,' xv] while they sojourned at the Iles Chausey. There these two celebrated observers ascertained for the first time that the compound Ascidians undergo a metamorphosis; that these animals, so immovably fixed in their adult state, are free during the first period of their existence and swim freely about by the aid of a long, broad tail. It is evident, however, that Savigny had previously seen the first, or tadpole, state of *Botryllus*, as in Plate xxi of his 'Mémoires' he gives two figures of it, but calls them, in the description of the plate, "two side-views of an egg arrived at its mature state."

* [Also in the same year by Sars, who said of the *Salpæ* that "it is not their larvæ which are developed into the perfect animal, but the progeny of the larvæ." See Steenstrup, *op. cit.*, p. 46.]

Lister made known, in 1834, his important observations on the circulation in a minute social Ascidian, afterwards named by Wiegmann *Perophora Listeri*. His remarks were published in the 'Philosophical Transactions,' and prove that, as in *Sertularia* and *Campanularia* (Hydroida), there is in this Ascidian a circulation common to many individuals or to a whole system of combined individuals. The author also gives, in his admirable memoir, a more complete account of the blood-circulation existing in the Tunicata than any that had previously been published. The figures are very good. The memoir is entitled "Some observations on the Structure and Functions of Tubular and Cellular Polypi and of *Ascidiæ*."

Then followed, in 1836 [in 'Weigm., Archiv.'], Sars' very curious observations on the metamorphosis of *Botryllus*, showing that one larva enclosed several young, united and already arranged in order; that it is in fact not a mere individual but a compound system of individuals swimming freely about in the external form of the usual tadpole larva. This extraordinary fact has been verified by the subsequent observations of many other naturalists.

In 1842 Milne-Edwards' beautiful memoir entitled "Observations sur les Ascidies Composées des côtes de la Manche" was published. It was read before the Académie des Sciences in 1839. In this memoir, which will ever be looked upon as one of the most admirable ever produced in this field of enquiry, the anatomy and embryology of these animals are treated at great length, and the author fully verifies the conclusions of Savigny. He supplies many points which were left undetermined by that indefatigable observer relative to the reproductive, vascular, and respiratory organs. He also describes several new species, and proposes to arrange the Ascidians in three divisions, namely, the Simple, the Social, and the Compound. The social Ascidians, however, pass by such a finely-graduated series from the compound to the simple

forms that it appears impossible to give to that group any definite boundaries. Milne-Edwards' paper is beautifully illustrated with coloured plates.

In the year 1845 Schmidt, in his work 'Zur vergleichenden Physiologie der wirbellosen Thiere,' made known the startling discovery that cellulose was a constituent of the test of *Ascidia* or *Phallusia mamillaris*. Löwig and Kolliker [in 'Ann. Sci. Nat.' (3), v] confirmed the statement of this distinguished naturalist, and ascertained that this substance was present in the outer envelope of different species of the genera *Phallusia*, *Cynthia*, *Clavellina*, *Diazona*, *Aplidium*, *Didemnum*, *Botryllus*, *Pyrosoma*, and *Salpa*, so there can be no doubt that cellulose is a constituent portion of the whole of the Tunicata.

Within the last few years several other important papers have appeared on the structure and development of the various forms of these animals, amongst which must be mentioned a memoir on the embryology, anatomy, and physiology of the Simple Ascidians by Van Beneden, published in the Memoirs of the Royal Academy of Belgium [xx (1847)]. From 1846 to 1852 Krohn published several important papers on the reproduction and development of the Tunicata. Professor Huxley's various contributions on the structure of the Tunicata were also published at about this time. His excellent memoirs "On the Anatomy and Physiology of *Salpa* and *Pyrosoma*," and "On the Anatomy of *Appendicularia* and *Doliolum*," were printed in the 'Philosophical Transactions' for 1851. In the former, Chamisso's facts as to *Salpa* are tested and confirmed, and the results of Krohn's paper on the same subject are verified. Papers of high merit on the Tunicata have also been published by Carus (1816-21), Meyen (1832-35), Eschricht (1839-43), Steenstrup (1842), Sars (1846-47), and others.

Little was done in working out the species of the Tunicata in early years; a small number only being described by a few distinguished naturalists, one of

whom, Baster ['Opusc. Subsec.' i (1760)], described a single species, probably a *Molgula*, which he named *Ascidium*, and thus this name was introduced into the nomenclature.

In the 12th edition of the 'Systema Naturæ' [vol. i, pt. 2], which appeared in 1767, only six kinds of simple Ascidians are included, three of which appear to have been added by Linnæus himself. They are placed in the class Vermes, under the generic denomination of *Ascidia*, a modification of Baster's name. The compound forms are contained in the genus *Alcyonium*, but there are only three or four species introduced.

In the 'Zoologica Danica' [1788–1816] Otto Fred. Müller described and figured twenty species [of *Ascidia* and one *Distoma*], many of the figures being very characteristic and the descriptions full and accurate, as is usually the case in the works of this admirable observer. Otho Fabricius gave eight species in his 'Fauna Grœnlandica' (1780).

After this time many distinguished naturalists enriched the fauna with additional species. Amongst them may be mentioned Peron (1804), Lesueur and Desmarest (1804–17), Savigny (1816–22), Cuvier (1817), Chamisso (1819), Macleay (1823), Quoy and Gaimard (1825–35), Lesson (1830), and Delle Chiaje (1841); and as a consequence of the combined efforts of these and other naturalists there were 147 species introduced in the second edition of Lamarck's 'Histoire naturelle des Animaux sans Vertèbres' [1835–43]. Since then many species have been added to the list, but it is not necessary in this monograph, devoted as it is to the British species only, to enter further into this branch of the subject than to observe that large as the number may be of the known Tunicata, there can be no doubt that a great many foreign species yet remain to be discovered. In fact [while the pelagic forms have attracted much attention], little has been done, comparatively, in the sedentary species.

We shall now turn our attention to the British

authors, and ascertain what progress has been made in determining our indigenous species up to the present time.*

[John Ray appears to have been the first English naturalist who mentions a Tunicate. In his 'Historia Plantarum' (1686), under the section "De plantis imperfectis," he describes as the *Bursa marina* of Bauhin the species now known as *Aplidium ficus*, but he does not record it as British. It is, however, a British species, and the first Tunicate recorded from our seas, being described and figured by John Ellis, as *Alcyonium pulmonis instar lobatum*, in his 'Natural History of the Corallines' (1755), from specimens found at Whitstable, on the Kentish coast.]

The next record† of a British Tunicate is met with in the 'Philosophical Transactions' for 1756; a *Botryllus* [found near the Lizard Point] is there described by Dr. Schlosser, and Ellis named it *Alcyonium carnosum*.

Borlase afterwards described the same species in his 'Natural History of Cornwall,' dated 1758, and it was in 1766 named *Alcyonium Schlosseri* by Pallas in his 'Elenchus Zoophytorum.' [Borlase also described and figured an allied species which Turton, in 1807, named *Alcyonium Borlasii*.]

In his 'Spicilegia Zoologica' [1774] Pallas describes four species [from the Cornish coast] on the authority of Gærtner, three of which are compound Ascidians; they are named *Ascidia mamillaris*, *Botryllus stellatus* [= *B. Schlosseri*], *B. conglomeratus*, and *Distomus variolosus*.

In Pennant's 'British Zoology,' 1777 edition, a species is described and named *Ascidia rustica*; this,

* The authors carried this history up to the year 1863, leaving many blanks in their MS. which they evidently intended to fill in. The editor has supplied the missing records and brought up the history to 1870, that being the year in which the last paper on the Tunicata by either of the authors appeared. All such additions are within brackets.

† "The first record" in the authors' MS.

however, is not a Tunicate; it is *Psolus phantopus* [a Holothurian], and is tolerably well figured.

[In the 'Natural History of Zoophytes' of Ellis and Solander (1786), the first two British Tunicates are described as *Alcyonium pulmonaria* and *A. Schlosseri*; and in 1803 Montagu, in his 'Testacea Britannica,' incidentally recorded *Ascidia mentula* from the coast of Devon.]

Turton gives two species in his 'British Fauna,' which was published in 1807. [These are *Ascidia rustica*, on the authority of Pennant, a record which we have seen is not that of a Tunicate, and *A. mamillaris*. He also enumerates, under the generic name *Alcyonium*, five species previously recorded, as *A. Schlosseri*, *A. Borlasii*, *A. Ficas* (sic), *A. conglomeratum*, and *A. ascidioides* (of Pallas = *Distomus variolosus*, Gærtn.); to which may be added *Ascidia mentula* to complete the British records to that date.]

In the course of the next eleven years the number of British species had increased to twelve, that being the extent of the list introduced in Fleming's 'British Animals' [1828]. They are named as follows:— *Pandocia conchilega*, *Clavellina lepadiformis*, *Pirena prunum*, *Ciona intestinalis*, *Phallusia mentula*, *P. rustica*, *Polyzona variolosa*, *Sydneum turbinatum*, *Alpidium ficus*, *Botryllus Schlosseri*, *B. conglomeratus*, and *Salpa moniliformis*, none of which appear to have been added to our fauna by the personal exertions of the author.

[Seven of the species enumerated above were additions to the British fauna since the publication of Turton's list in 1807. Three of these were recorded by Professor Jameson from Leith shore in 1811 ('Mem. Wernerian Soc.,' i), and were referred by him to Müller's *Ascidia rustica*, *A. prunum*, and *A. conchilega*; one, *Ciona intestinalis*, was added by Pennant, from the Menai Straits, as *Ascidia virescens*, in the 1812 edition of his 'British Zoology,' in which he changed the name of his *Psolus* from *Ascidia rustica* to *A. eboracensis*, recognising that it was not Müller's *A. rustica*;

two, *Clavelina lepadiformis* and *Sidnyum turbinatum*, were described by Savigny in his 'Animaux sans Vertèbres' (1816) from specimens sent to him from the English coast by Dr. Leach; and one, *Salpa moniliformis*, was described by Dr. Macculloch in his 'Western Isles of Scotland' (1819). Fleming omits Gærtner's *Ascidia mamillaris* and Turton's *Alcyonium Borlasii*.

In the 'Edinburgh Philosophical Journal' for 1830 Dr. Coldstream recorded four species from Scotland, describing two, *Synoicum rubrum* from Lamlash Bay, Arran, and *Ascidia rugosa* from East Loch, Tarbet, as new. The others are *Sidnyum turbinatum* and *Ascidia prunum*, neither being a new British record.]

Dr. Lister described two new species in the 'Philosophical Transactions' for 1834. One of these was, in the following year, named *Perophora Listeri* by Weigmann; the other, which was merely designated *Polyclinum* by its discoverer, was afterwards named *Leptoclinum Listerianum* by Milne-Edwards.

[In the same year (before the publication of Lister's paper) George Johnston ('Mag. Nat. Hist.,' vii) described two new species of *Aplidium* from the Berwick coast, *A. fallax* and *A. nutans*; and Robert Templeton, under the initials "C. M." (*loc. cit.*), described and figured as new British species *Ascidia ? gemina* and *A. ? anceps*, the latter from Belfast Lough.* In 1839 Sir John Dalyell ('Edin. new Philos. Journ., xxvi) described the development through the tadpole state (termed "spinula" by him) of a simple and a compound Tunicate from the coast of Scotland which he named respectively *Ascidia papilla* and *Aplidium verrucosum*. In the 'Report of the British Association' for the same year Forbes and Goodsir recorded *Ascidia intestinalis* from the Orkney and Shetland Islands, naming as new species, but not describing, *A. echinata*, *A. rugosa* (both pre-occupied names), and *A. rubens*; and in the 'Report'

* The locality for *Ascidia gemina* is not given, but in 1840 William Thompson ('Ann. Nat. Hist.,' v) recorded it from Strangford Lough.

for the following year they described a new genus, *Pelonaia*, with two new species from the Scottish seas, *P. corrugata* and *P. glabra*. This year (1840) witnessed a considerable addition to our list, eighteen species being recorded by Thompson ('Ann. Nat. Hist.,' v) from the Irish coast, of which the following ten were new to our fauna :—the *Ascidia echinata* of Linnæus, Müller's *Ascidia venosa*, *A. aspersa*, *A. scabra*, *A. parallelogramma*, and *A. orbicularis*, and Savigny's *Cynthia claudicans*, *Distoma rubrum*, *Botryllus Leachii*, and *B. polycyclus*.]

Macgillivray, in his 'History of the Molluscous Animals of Aberdeen, Kincardine, and Banff,' published in 1843, describes only four species [as *Cynthia tuberosa*, *Ascidia prunum*, *A. opalina*, and *A. intestinalis*], the first two of which were new to our shores. One of the four was wrongly identified with Müller's *Ascidia prunum* [being the species since named *A. sordida*], and another, *A. opalina*, is the *A. parallelogramma* of Müller.

[In the following year William Thompson, in his "Additions to the Fauna of Ireland" (Ann. Nat. Hist.,' xiii) recorded eleven species of which the following eight were new to our shores :—*Ascidia canina*, *Amaroucium proliferum*, *Leptoclinum gelatinosum*, *L. maculatum*, *L. asperum*, *L. durum* (as *aureum*), *Botryllus gemmeus*, and *B. bivittatus*; and in 1846 (*op. cit.*, xviii) he added *Botryllus albicans* and *B. rotifera*.]

Sir John G. Dalyell's 'Rare and Remarkable Animals of Scotland' was published in 1847–48. In it upwards of twenty species of Tunicata are figured and described; but in most instances the figures and descriptions are not sufficient to enable us to determine the species. It is, therefore, quite impossible to say whether the list contains anything new or not. Many of the species are not named, and indeed several of those which are named are erroneously identified with previously-known species. The figures, though elaborately got up, are of but little use. Sir John unfortunately adopted the erroneous principles that a naturalist

should not illustrate his own works and that the figures should not be larger than life. A natural-history draughtsman's work will be complete in proportion to his knowledge of his subject, and who can be so well acquainted with his subject as the naturalist who has determined the species? An object ought to be drawn of such size as is necessary for the accurate rendering of form and character. In minute and complicated objects this can only be done by enlarging the representation. So far as we are able to ascertain not a single new Tunicate has been added to the British fauna by Sir John Dalyell's labours.

The 'History of British Mollusca' by Forbes and Hanley [in 4 volumes] bears the date of 1853, though its publication commenced in 1847.* Seventy-three species are described in this work, [sixty in the first volume,] seven of which were entirely new to science, namely *Leptoclinum punctatum*, *Molgula oculata*, *Cynthia quadrangularis*, *C. informis*, *C. tessellata*, *C. limacina*, and *C. morus*; and thirteen were for the first time recorded as British [,namely *Polyclinum aurantium*, *Amouroucium Nordmanni*, *A. argus*, *Botryllus violaceus*, *B. smaragdus*, *Botrylloides rubrum*, *Ascidia arachnoidea* (= *A. mamillata*), *A. vitrea*, *Molgula tubulosa*, *Cynthia microcosmus*, *C. grossularia*, *C. ampulla*, and *C. aggregata*]. In this work, also, there is found the first record of a well-authenticated *Salpa* in our seas, *S. runcinata*. Dr. Macculloch was the first to notice the presence of this interesting genus in the British seas, but his description and figure are not sufficient for the determination of the species.

There is something more than a mere record of species in the 'British Mollusca'; it contains an excellent *résumé* of the then state of knowledge of this

* Pp. 1–477 of the first volume came out in twelve monthly parts, dated 1848, but the first part, for January, pp. 1–40, in which are nearly all the Tunicata, may have been issued before the end of the year 1847. Alder and Hancock's date is therefore allowed to remain here, but in the synonymy the date given for the first part is that which appeared on its cover, 1848.

interesting though somewhat neglected branch of malacology, and the genera and species are all well and fully described.

In the 'Catalogue of the Mollusca of Northumberland and Durham' published in the 'Transactions of the Tyneside Naturalists' Field Club' in 1848, the authors of this Monograph enumerated thirty-one species of Tunicata; of these sixteen are simple Ascidians, one is a social Ascidian, and fourteen are compound Ascidians. In all thirteen were for the first time described and named, as follows :—*Cynthia coriacea*, *Molgula arenosa*, *M. citrina*, *Ascidia sordida*, *A. albida*, *A. depressa*, *A. elliptica*, *A. pellucida*, *Botryllus rubens*, *B. virescens*, *B. castaneus*, *Botrylloides radiata*, and *B. ramulosa*.

[In 1850 Mr. Joshua Alder added to these, in his "Additions to the Mollusca," etc., in the same publication, a new species, *Molgula siphonata*; and in 1851 Forbes and Goodsir ('Trans. Roy. Soc. Edinb.,' xx) described a new species, *Syntethys hebridicus*, from the Hebrides. In this year, also, the "Zoology of the Scilly Isles" by Victor Carus, appeared ('Proc. Ashmolian Soc.,' Oxford, vol. ii). In it Carus records fourteen Tunicates and founds a new genus, *Thylacium*, describing as new species *Thylacium Sylvani* and *Amareucium edentulum*, and also adding to our fauna *Didemnum candidum* and *D. gelatinosum*.

In the second volume of Forbes and Hanley's 'British Mollusca' (1849), twelve of Alder and Hancock's species of 1848 are introduced, including *Molgula arenosa* substituted for *M. tubulosa* of their first volume, *M. citrina* being omitted; and in the fourth volume (1852) *Syntethys hebridicus* is added. In this volume, also, there is the first notice of the occurrence of *Appendicularia* in our seas, as having been found "off the north coast of Scotland in 1845," but the name of the species is not given. It was probably *A. flagellum*, Cham., which was recorded from Tenby (as *A. flabellum*) by Professor Huxley in 1856 ('Quart. Journ. Micr. Sci.,' iv). The number of species

admitted into this work (including *Appendicularia*, sp. ind.) was thus raised from 60 to 73.]

In his 'Natural History of Ireland' [iv (1856)] Mr. Thompson enumerates 42 species, of which two are new. [*Amoroucium albicans* is one of these; the other appears to be that named *Ascidia mamillaris*, Delle Chiaje, which is not Müller's *A. mamillaris*, previously recorded, and probably not Delle Chiaje's species.

In this year (1856) Philip Henry Gosse brought out his 'Manual of Marine Zoology for the British Isles,' in which he enumerates 66 Tunicates. These are the 60 in Forbes and Hanley's first volume, *Aplidium verrucosum*, *Amœræcium albicans*, *Syntethys hebridicus*, *Clavellina producta*, *C. pumilio* ?, and *Appendicularia flagellum* ?, the two species of *Clavellina* appearing to be first records. Gosse omits Alder's fourteen records of 1848 and 1850, and the four records of Carus (1851).]

The Rev. A. M. Norman published [in 1857] a list of the "Mollusca of the Firth of Clyde" ['Zoologist,' xv] in which are enumerated sixteen species of Tunicates as denizens of that district, but not one of them was new to the British fauna.

[In 1860 Mr. John Stanger recorded in the 'Transactions of the Tyneside Naturalists' Field Club' (iv), from Craster, Northumberland, *Cynthia vestita*, a new species named and then only briefly described by Mr. Alder. In the same year Mrs. Merrifield, in her 'Natural History of Brighton,' recorded eight species, seven of which appear to be new to Brighton, but not one new to Britain.

The "List of the British Marine Invertebrate Fauna," drawn up for the Dredging Committee of the British Association by Mr. Robert McAndrew ('Rep. Brit. Assoc.' for 1860), enumerates 73 species of Tunicata, including *Appendicularia*, sp. ind., but this list was solely compiled from Forbes and Hanley's 'British Mollusca,' and therefore omits all the species added to our fauna, except *Syntethys hebridicus*, from 1848 to the date of its publication in 1861.]

In 1863 Mr. Joshua Alder published, in the 'Annals of Natural History' [ser. 3, xi], "Observations on the British Tunicata," in which the following twenty-two new species are described:—*Ascidia pustulosa*, *A. obliqua*, *A. rudis*, *A. plebeia*, *A. aculeata*, *A. pulchella*, *Molgula socialis*, *Cynthia squamulosa*, *C. rosea*, *C. sulcatula*, *C. granulata*, *C. opalina*, *C. violacea*, *C. glomerata*, *Thylacium Normani*, *T. variegatum*, *Polyclinum succineum*, *P. cerebriforme*, *Amaræcium papillosum*, *Parascidia flabellata*, *Botrylloides sparsa*, and *B. pusilla*; and two other species [*Amaræcium pomum* and *Distoma vitreum* of Sars] are for the first time recorded as British. [The name *Cynthia comata* is also newly proposed for the *C. ampulla* of Forbes, not of Bruguière; and for two species, considered to have been referred in error to Savigny's *Sidnyum turbinatum*, the names *S. Flemingii* and *S. Forbesii* are proposed.] Remarks are made on seven other species and on several genera, and the spiral arrangement of the minute vessels of the branchial sac in *Ascidia* [*Corella*] *parallelogramma* and *Molgula arenosa* is described and figured.

From the above summary, exhibiting the sequence of the discovery of the British Tunicata, it appears that up to 1863 one hundred and six* species stand recorded. Since that date several more have occurred, chiefly by the exertions of our friends, and more particularly by the never-ceasing research of the Rev. A. M. Norman and Mr. J. Gwyn Jeffreys. The researches of Mr. Norman have not only added new species to the list, but have also very materially increased our knowledge of their distribution in the British seas. We are indebted to many other eminent naturalists for similar services, amongst whom we have pleasure in mentioning our friends Dr. J. S. Bowerbank, Prof. Allman, the

* "Ninety-nine" in the authors' MS., but to the 73 in Forbes and Hanley's 'British Mollusca' must be added *Molgula citrina* (1848), *M. siphonata* (1850), *Thylacium Sylvani*, *Didemnum candidum*, *D. gelatinosum*, and *Amaroucium edentulum* (1851), *Clavelina producta* and *Amaroucium albicans* (1856), *Cynthia vestita* (1860), and the 24 records of Alder (1863). All these additional species are included in this Monograph.

Rev. Thomas Hincks, Dr. G. S. Brady, Mr. George Hodge, Mr. A. J. More, and Mr. C. W. Peach.

[Between 1863 and 1870 several valuable papers on the British Tunicata and their distribution appeared. It will suffice to mention the more important contributions of Dr. W. C. McIntosh, the Rev. A. M. Norman, and the authors of this Monograph.

In 1865 Mr. Alder reported on the Mollusca found in deep-sea dredging on the coasts of Northumberland and Durham in 1862 to 1864 ('Nat. Hist. Trans. Northumb. and Durh.,' i), giving a list of ten species collected along the coast and on the Dogger Bank, but not adding any new British record. In the same year *Salpa spinosa* was added to our fauna by Dr. McIntosh from the Hebrides, and the Rev. A. M. Norman from Guernsey, but Mr. Norman's paper communicating his discovery to the British Association was not published. Dr. McIntosh's paper was read before the Royal Society of Edinburgh and published in the following year ('Proc.,' v). In it he gives a list of twelve species from North Uist, Outer Hebrides, including this *Salpa* and a new species of *Cynthia* which he named *C. uistiæ*. This list was considerably extended in 1867 by Mr. Alder, who enumerated nineteen species in a report on dredging among the Hebrides in July, 1866 ('Rep. Brit. Assoc.' for 1866), but without making any addition to the British fauna. In the "Shetland Final Dredging Report" of the British Association ('Rep. Brit. Assoc.' for 1868) the Rev. A. M. Norman enumerated twenty-seven species determined by Mr. Alder, adding considerably to our knowledge of the distribution of the Tunicata in the Scottish seas, but not giving any new British record, for although he gives *Ascidia obliqua*, *A. rudis*, *A. plebeia*, and *Polyclinum succineum* as "species added to the British fauna during the recent dredging" (*i. e.* 1861–67), these species had been sent by him to Mr. Alder, who described them in 1863.

The last paper to be mentioned is one by Mr.

Hancock, published in 1870, "On the Larval State of *Molgula*; with Descriptions of several new Species of Simple Ascidians" ('Ann. Nat. Hist.,' ser. 4, vi), in which he comes to the conclusion, from his own researches and those of Van Beneden and Lacaze-Duthiers, that there are two distinct modes of development in closely-allied genera of the Tunicata, the tadpole-condition being non-essential, a discovery which he said might have some effect on the theory of the relationship of this group with the Vertebrata. He describes two new genera, *Corella* and *Eugyra*, and the following nineteen new species:—*Ascidia plana*, *A. Alderi*, *A. rubro-tincta*, *A. rubicunda*, *A. robusta*, *A. mollis*, *A. crassa*, *A. inornata*, *A. producta*, *A. elongata*, *A. affinis*, *A. Normani*, *Corella larvæformis*, *C. ovata*, *Ciona fascicularis*, *Molgula simplex*, *M. inconspicua*, *M. complanata*, and *Eugyra globosa*.

These species, with those previously described by the authors, are for the first time figured in the present Monograph.]

Having now gone over the history of the discovery of the Tunicata, both structural and zoological, we shall give in detail a full account of the organization of the entire class.*

* As Albany Hancock died before the conclusion of his investigation of the Tunicata, and had not written that portion of the introduction to this work which would have embraced his latest views of their anatomy and physiology, a paper which he contributed to the Linnean Society of London in 1867 is here reprinted from the Journal of the Society by permission of the Council. The only alterations which have been made in this paper are the substitution for *Ascidia* of the generic names *Ciona* and *Corella*, and for *Molgula* of the new generic name *Eugyra*, for certain species subsequently referred to these genera by the author, and of *Styela* for *Stycla*, as Savigny's genus erroneously appears in the paper; also the insertion of the names of a few species which were then undescribed, of sub-headings, and of illustrations from the author's drawings. Some portions of the paper which treat specially of the anatomy and physiology of *Ascidia* and of a few other genera are repeated, with or without modification, in the descriptions of those genera.

ON THE ANATOMY AND PHYSIOLOGY OF THE TUNICATA.

By Albany Hancock, F.L.S.

[From 'Journ. Linn. Soc.,' Zool., vol. ix, pp. 309–336.]

Having employed myself recently in the investigation of the Tunicata (their anatomical structure and physiology) with a view to a monograph of the British species, which my late lamented friend Mr. Alder and I had undertaken to prepare for the Ray Society, some very interesting anatomical facts have come to light; and I now propose to give a succinct account of the more important of these, believing that they cannot fail to be acceptable to those naturalists who may have studied these low but not by any means unattractive mollusks. I reserve, however, for some future occasion a more complete and detailed description.

When I took up this subject, I had little expectation of meeting with much that was new; for perhaps in no other group of the Molluscan subkingdom has the anatomy been so frequently and so ably investigated as it has been in the Tunicaries; and, indeed, in them, all the leading points appear to have been fully determined; but experience proves, nevertheless, that much of interest has been left unobserved, quite sufficient to reward the labour of re-examination, and seemingly ample enough to modify some of the more important morphological determinations.

This unexpected result may, in part, be owing to the fact that, while my researches have been chiefly confined to the simple Ascidians, it is apparently to the compound, social, and pelagic forms that the greatest attention has been hitherto given. Thus it happens that numerous details have remained until now unnoticed in the former group.

The Tunics.

There is something fresh to record in nearly all the visceral organs, but in none so much perhaps as in the vascular and respiratory systems. Before entering, however, on such new matter, it will be well to say a few words respecting the tunics, so characteristic of these animals. In all the various forms that have been examined there is no great difficulty in deter-

mining the presence of three tunics, or envelopes—namely, the test or outer tunic, the mantle or inner tunic, and the lining membrane or inner tunic of Prof. Huxley.* The lining membrane and mantle are always, to a greater or less extent, adherent to each other, and have, except where there is an abdomen developed, all the viscera and the lacunary portion of the blood-system placed between them. On the other hand, the mantle and test in *Ascidia* and *Molgula* are always free, except at the distal extremity of the respiratory tubes, where they are united; there is also an attachment at the point where the vascular trunks enter the test. But in the genus *Styela* (Savigny's third tribe of *Cynthia*) the test is always more or less firmly attached to the mantle throughout, though at the respiratory orifices the adhesion is greatest. In all the species, however, that have been examined, with the exception of one (a small undescribed species [*S. humilis*, sp. nov.]), these two envelopes may be separated without much difficulty in specimens preserved in spirit. In the exceptional case alluded to the mantle is exceedingly delicate; and hence probably arises the difficulty of separating it from the test. In this genus, as well as in *Ascidia* and *Molgula*, blood-vessels pass from the body to the test. It is therefore likely that vessels will be found ramifying in the outer tunic in all the simple Ascidians. In *Pelonaia* the adhesion of the mantle and test is not by any means so remarkable as was originally supposed; and, indeed, in this form they are as easily divided as they usually are in *Styela*. Also in *Clavelina* these two tunics are slightly adherent throughout, while in *Salpa* they appear to be as free as they are in *Ascidia*.†

It should be mentioned that, in a living state, unless the mantle be violently contracted, there is no actual vacant space, or space filled with fluid, as has been asserted, between it and the test; even in those species which have these tunics comparatively free the two surfaces lie in close contact. When the animal is dead, however, and preserved in spirit, the body enclosed in the mantle does not by any means occupy the entire space within the test, but lies somewhat shrivelled, and frequently quite free (fig. 1, p. 22), just as commonly happens with the animal of the Lamellibranchs within its shell under similar circumstances.

* This tunic was first pointed out by M. Milne-Edwards, in his work on the 'Ascidies Composées,' p. 54.

† I have examined only one species of *Salpa*, namely *S. spinosa*, and the specimens were preserved in alcohol.

The chief function of the test, like that of the shell in the higher mollusks, is no doubt to protect the comparatively soft and delicate portions of the animal that lie within it. But it will also act, by its resiliency, as a counterpoise to the muscular contractility of the mantle, which lines it as it were. In those species, such as *Styela tuberosa*, in which the mantle and test are adherent throughout, this action is readily understood; it is not, however, quite so obvious in the species which have these two tunics comparatively free, as they are universally in *Ascidia* and *Molgula*. But we have just seen that, in such

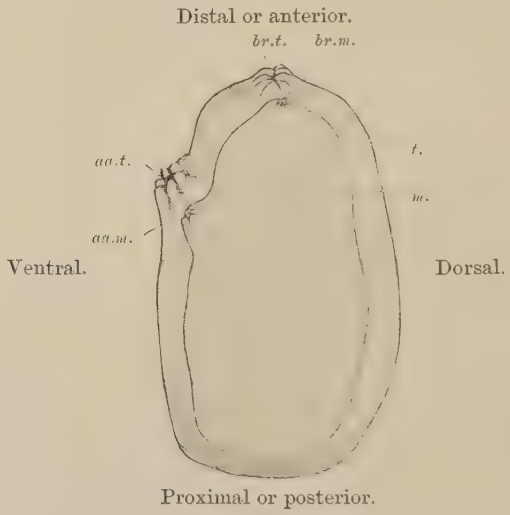


FIG. 1.—*Ascidia scabra*. Left side. *t*. Test (outer tunic). *m*. Mantle (inner tunic). *br.t*. Branchial aperture of test. *br.m*. Branchial aperture of mantle. *aa.t*. Atrial aperture of test. *aa.m*. Atrial aperture of mantle. Three times natural size. From a specimen preserved in spirit, with the mantle shrunk.

instances, the inner surface of the test, and the outer surface of the mantle, lie in close contact with each other. Now, as under all ordinary circumstances the pressure of the water inside the mantle must be as great as that of the water resting against the outer surface of the test, and as no water can possibly enter between these two tunics, it is clear enough that they will be held together with no inconsiderable force. Thus, when the muscles of the mantle contract, diminishing the bulk of that organ, the test will be drawn in after it; and so soon as the muscles of the former relax, the latter, through the elasticity of its walls, will expand, and the mantle will be constrained to do so likewise.

The Digestive System.

The most interesting matter that I have to communicate respecting the digestive system relates to the biliary apparatus. A remark or two, however, may be made, in the first place, upon the alimentary canal, which, in all the species that have come under my inspection, makes its first bend towards the dorsal region, assuming that to be the dorsal aspect where the endostyle is placed. The intestine then usually ascends and crosses over (in a more or less undulatory course, sometimes forming one or two loops) to the opposite or ventral side, where it again ascends to reach the cloaca, into which, in the Ascidians, it invariably opens. The walls, from one end of the organ to the other, are particularly firm, and do not collapse even in preserved specimens. The lower portion of the intestine is the most delicate; but even here the wall rarely shrinks. The stomach is well marked, though it is never very bulky, and is usually lined with a stout mucous membrane, which is frequently plaited or wrinkled, sometimes in a symmetrical manner, the plaits extending into the œsophagus on the one hand, and into the intestine on the other. In the latter organ this membrane is thrown up so as to form a very conspicuous groove which extends from the stomach to that portion of the intestine which may be termed the rectum. In *Styela tuberosa*, and some other species, however, this groove extends the whole length of the intestine.

The food of the Tunicaries is extracted from sedimentary matters; there is no power of selection in the first instance; those particles which can be, are digested; the others, chiefly composed of sand and mud, are rejected in the usual manner. The sedimentary aliment is sifted from the water in the respiratory sac by the aid of the branchial network, and is then carried across the organ by the action of cilia; but no definite arrangement of the particles takes place until they arrive at the oral or ventral lamina, where they are formed into a cord of some tenacity, apparently through the agency of mucus, and are carried thus moulded along this lamina to the oral orifice, and so swallowed. This alimentary cord is conducted through the digestive tube, and is rejected in the same form by the anus and excurrent tube. The cord-like fæces may frequently be seen through the wall in the lower portion of the intestine, having very much the appearance of a convoluted tube lying within the canal. In some of the lower forms, however, it is broken up into elongated pellets.

All this is very similar to what takes place in connexion with the alimentation in the Lamellibranchs; but in them the lateral currents of particles are as well defined as the main or central ones.

Molgula, and Savigny's first and second tribes of his genus *Cynthia,* appear to be the only forms among the simple Tunicates that have hitherto been described as possessing a well-developed liver. This organ is always sufficiently distinct in these groups, and usually presents a laminated structure, but is occasionally composed of tubular tufts or lobes, the colour

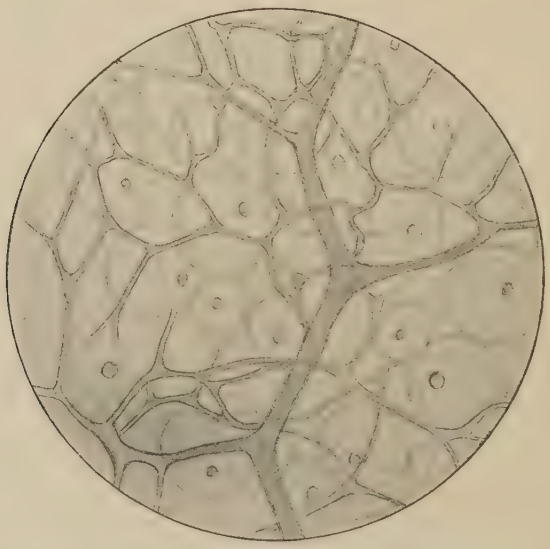


Fig. 2.—Hepatic tubes and globular vesicles in *Ascidia sordida.* Highly magnified (¼ in. object-glass).

being generally of a dark olive-green. I find, however, a true hepatic organ in all the other genera examined (namely *Ascidia, Styela, Pelonaia, Clavelina,* and *Perophora*), quite distinct from that gland-like substance coating the alimentary tube in the first of these forms, and which has occasionally been considered to subserve the hepatic function.

This substance is of a very peculiar character, and it is difficult to say what its office really is. In all the *Ascidiæ* it forms a pretty thick coating over the stomach and intestine, and is composed of comparatively large globular vesicles with thin reticulated walls, each having a large, opaque, simple or compound nucleus on one side (fig. 2). These vesicles have no

communication with each other, though they lie in contact and are cemented together; nor are they connected with any duct, or in any way open into the alimentary tube. Blood-channels are hollowed out, as it were, amidst the vesicles; and the reproductive organs ramify throughout the agglomerated mass which overlies, for the most part, the true hepatic organ. These vesicles will therefore act as a sort of packing to the parts of these organs, and will give support and protection to them, whatever higher function they may have to perform. They may likewise assist the heart in the performance of its work by their resiliency when the mass is gorged with blood; for it is evident that, when the interstices or blood-channels

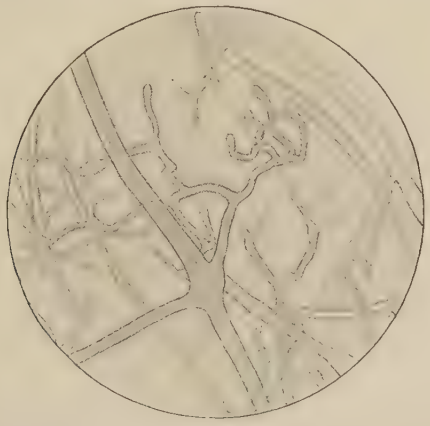


FIG. 3.—Hepatic tubes in *Ascidia affinis*. The branches terminate in blind sacs, and are rounded and enlarged a little. Highly magnified (1 in. object-glass).

are filled, the vesicles will be more or less collapsed in proportion to the pressure of the blood-current; and when the latter changes its direction the reaction will be assisted by their expansion. In our present state of knowledge, however, nothing positive can be said of the uses of this very curious structure.

The true hepatic organ, as already intimated, lies beneath this vesicular mass, and forms a thin coating on the surface of the intestine. In all the examples observed it is composed of delicate tubes, which divide dichotomously, but frequently without much regularity. At the points where the branches are given off, the tubes are usually enlarged, and the twigs terminate in rounded extremities more or less inflated (fig. 3).

The ultimate divisions of the organ are so minute that they can only be observed by the aid of the microscope after a portion of the intestinal tube has been removed, laid open, and deprived of the mucous membrane, so as to render the tissue as transparent as possible.

In *Ascidia mentula* the dichotomous division of the tube is very obvious, and the enlargements or ampullæ at the junction of the branches are greater than usual, and they assume a triangular form; also oval enlargements frequently occur along the branches, which latter uniting go to form two long slender ducts that pass backwards within the loop of the intestine buried amidst the vesicular substance already described, and at length open through the left wall of the stomach about midway between the cardia and pylorus, towards the anterior margin. These two ducts come from the middle portion of the intestine; another duct, passing from the lower part of the intestinal tube, unites with one of those first mentioned just before it sinks into the wall of the stomach. All the three ducts are exceedingly slender; and for their detection it is necessary to dissect carefully the vesicular matter within which they lie buried: when thus exposed their white walls can easily be traced, with the aid of a good lens, running amidst the comparatively dark surrounding tissue.

In *Ascidia sordida* and *A. scabra* the arrangement of the parts of the hepatic organ is similar to that in the above species; but in *Corella parallelogramma* the minute structure is considerably modified. In this species there is a minute network of anastomosing tubes spread over the intestine, the tubes being divided into systems by the interruption of the anastomoses along certain lines where the twigs end in blind sacs, which are occasionally a little enlarged and rounded. The main branches leading from the network exhibit a tendency to divide dichotomously, and unite to form two slender ducts which pass at once from the intestine to the left side and close to the posterior margin of the stomach, into which they pour the biliary secretion a little in advance of the pylorus.

In *Pelonaia* there is only one hepatic duct, which is very slender, and passes in a fold of the lining membrane or "inner tunic" of Huxley that extends from the intestine to the right side of the stomach, a little way in advance of the pylorus. Before terminating, it receives a twig or two from the surface of the stomach; so that in this genus the liver is apparently not confined to the intestine, but is also spread over a portion of the stomach. The ultimate twigs divide

dichotomously with considerable regularity and terminate in round or ovate vesicles, which are very numerous and form a distinct, opaque, yellowish layer.

The liver in *Styela* is not more conspicuous than it is in *Ascidia*. It is well developed, nevertheless, and is provided with its secreting vesicles and ducts. In *S. tuberosa*, and, indeed, in all the members of this genus that have come under my observation, there is a fold of the lining membrane within the loop of the alimentary tube, which passes between the stomach and intestine. This fold is united to the pyloric end of the stomach, where there is a cæcal prolongation of that organ. The hepatic ducts lie within this fold; and before they reach the stomach, in this species, they unite to form a simple, slender duct, which opens into the left side of the cæcum. The branches of the ducts ramify dichotomously over the lower portion of the intestine, and communicate with comparatively large rounded vesicles arranged like those in *Pelonaia*.

In *Clavelina* there is only one hepatic duct, which passes from the middle portion of the intestine and opens into the alimentary tube immediately below the rounded stomach. The branches of the duct ramify over the intestine, dividing dichotomously, and ending in comparatively large, oval vesicles. Exactly the same form of organ is observed in *Perophora*; but in this genus the duct opens through the right wall of the stomach, near the pylorus. The hepatic organ in this interesting form was undoubtedly noticed by Dr. Lister; for he figures and describes, in his well-known memoir in the 'Philosophical Transactions,'* "transparent vessels" ramifying over the intestine; but he does not appear to have observed the terminal vesicles, and the termination of the duct in the stomach, or he scarcely could have supposed, as he did, that the vessels he described were lacteals.

With this exception, this peculiar form of the hepatic organ seems entirely to have escaped notice until A. Krohn gave a very good description of a similar structure in a paper "On the Development of the Ascidians," published in Müller's 'Archiv,' 1852–53†. The species examined by this naturalist

* "Some Observations on the Structure and Functions of Tubular and Cellular Polypi and of Ascidiæ," 'Phil. Trans.,' 1834, p. 380.

† See 'Scientific Memoirs,' edited by Henfrey and Huxley, p. 328. Before I was aware of the discovery by Krohn, I had worked out the details of the hepatic organ in the genera mentioned in the text; it was therefore highly satisfactory to find his description of this organ in *A. mamillata* agree so closely with my observations, particularly in *A. mentula*.

was *Ascidia mamillata*; and although he appears to have traced with great accuracy the development of the organ, he seems to have failed in detecting the duct in the adult animal. From the general characters, however, obtained by his examination of the young and adult combined, he is disposed to conclude that the "secretion prepared in the cæca must be accessory to digestion; but whether or not the watery secretion is bile, and the gland therefore a liver," he concludes, "must for the present be left undecided." Nevertheless, after the above description of the numerous modifications of the organ, and particularly when the position of the duct in relation to the alimentary tube is taken into account, few physiologists will be inclined to doubt that this organ is a true liver, though low and rudimentary in structure.

The Reproductive Organs.

The reproductive organs are well developed in the Tunicates; and in all of them the two sexes are combined in the same individual, though the male and female elements are always secreted by distinct organs, which, however, frequently compose one or more compound masses that have the parts so intimately united that careful examination is required to detect them; hence in several of the *Cynthiadæ* the testis has been entirely overlooked: the oviduct and *vas deferens* are likewise constantly distinct.

In *Ascidia sordida* the ovary is composed of numerous tubular branches which ramify in a radiating manner over the left side of the looped portion of the intestine (Pl. XIII). The oviduct passes through the loop, and, following the curvature of the intestine, opens by the side of the anus into the cloaca. The *vas deferens* terminates near to the same point, and is adherent to the oviduct throughout its course [as in *A. mentula*, see fig. 12, p. 62]. In the vicinity of the ovary it receives several much attenuated branches from either side of the intestine; these divide dichotomously, the ultimate twigs terminating in elongated and irregularly-lobulated vesicles which are spread over the intestinal tube, and which also exhibit a tendency to dichotomous division: these vesicles secrete the male element.

In *A. scabra*, *A. affinis*, *A. mentula*, and *A. venosa* the same arrangement of the reproductive organs is apparent; but the ovary in *A. mentula* is a lobulated organ, and, lying within the loop of the intestine, is seen at both sides of the alimentary tube, and consequently has the appearance of being

double; and in *A. venosa* the male vesicles are exceedingly minute and are very numerous. In *Corella parallelogramma* the genitalia have much the same disposition; the ovary, however, which is branched and lobulated, is spread out on both sides of the alimentary tube—as is likewise the male organ, the secerning vesicles of which are clustered into dendritic systems.

These organs, however, are modified to a much greater extent in the *Cynthiadæ*—in many of which it is not easy to determine the parts, on account of their intimate union; and very careful examination is requisite in these cases. In *Styela tuberosa* the so-called ovaries are very numerous, and are studded over the inner surface of the mantle on both the right and left side of the body, causing the lining membrane to bulge out. When fully developed they form protuberant, ovate, orange-coloured masses, each having at the attenuated extremity a projecting nipple-like papilla. This is the oviduct, leading out of the ovarian mass or ovigerous sac; for each mass is really a sac in the walls of which the ova are developed. And firmly attached around the base of these sacs is a series of pale oval vesicles which are sunk in the substance of the mantle, and which form for each sac a sort of cup within which it rests. These vesicles are the male secreting organs, and their ducts, extremely delicate tubes, pass upwards over the surface of the sac, and go to join, on the median line, a slender *vas deferens*, which, passing forward, terminates at the extremity of the short nipple-like oviduct above described. Thus it is seen that the so-called ovarian mass is a compound organ, combining both the male and female parts, each with its proper secreting organ and duct. There are therefore as many oviducts and outlets for the male secretion as there are compound reproductive masses; and the eggs must be shed everywhere into the space between the branchial sac and the wall of the respiratory chamber, and afterwards carried by the atrial currents to the cloaca, and so pass out, as usual, by the excurrent tube.

These reproductive masses should not be confounded with other very similarly-formed bodies that everywhere stud the mantle, and fill up, to a considerable extent, the spaces between the former. These latter bodies are most frequently pedunculate, and are sometimes as large as the reproductive masses, from which they chiefly differ in colour, being pale, somewhat pellucid, and almost homogeneous in structure. They do not seem to have any high functional import, their office apparently being to form, along with the generative bodies, a sort of pad

or level surface for the support of the branchial sac, which otherwise might suffer from the inequality produced by the genitalia. These peculiar organs are found in all the *Cynthiadæ* that have been examined, including *Pelonaia;* and in all the reproductive organs project boldly from the surface of the mantle.

This arrangement of the reproductive organs also occurs in *Styela mamillaris,* and in two undescribed species of the genus, recently obtained by the Rev. A. M. Norman at Guernsey.

In *Thylacium aggregatum* the same disposition of these parts is also found to exist.

In *Cynthia ovata,* an undescribed species allied to *C. squamulosa,* we have a very remarkable modification of these organs. Here there are only two generative masses—one placed immediately above the alimentary tube, the other within the intestinal loop. They are elongated and fusiform, each being composed of a double parallel series of squarish nodules in which both ovary and testis are combined. Each mass has its own proper oviduct and *vas deferens,* which pass forward, united, between the series of nodules, and, extending a little way in advance of the organ, open into the cloaca near to the anal orifice.

But perhaps the most interesting variety of this apparatus occurs in *Pelonaia,* in which there are two elongated tubular ovaries, each being bent so as to form a wide loop; they are attached throughout to the mantle, and bulge out the lining membrane; one is on the right, the other on the left of the branchial sac in front of the greater portion of the alimentary tube. The oviducts advance a short way beyond the ovaries, and open into the cloaca, one on each side of the intestine, but considerably in advance of the anal orifice. The testis is composed of numerous elongated, simple or lobed vesicles, which are placed with one end in contact with the sides of the ovaries, and are arranged in parallel order at right angles to them, fringing both sides of these organs from end to end. From the proximate extremities of the vesicles extremely delicate ducts pass across the surface of the ovary, to which they are attached, and go to join the *vas deferens* that extends along the middle line from end to end of each ovigerous organ, and, advancing along the oviduct, terminates at the extremity of that tube.

I have not met with this peculiar arrangement of the genitalia in any other species, though, after all, it is but as it were an amplification of that which we have seen to exist in the compound genital masses in *Styela tuberosa* and its imme-

diate allies. If one of these masses were greatly elongated, so as to become tubular, and if the male vesicles were increased in number, their lower extremities pulled from beneath the ovigerous sac and stretched out on the mantle, we should have something very similar to that which subsists in *Pelonaia*.

Another modification of these organs occurs in *Styela variabilis*, an undescribed species related to *Cynthia canopus*, Savigny. In this the ovaries assume the form of distinct, wide, slightly undulated tubes, of which there are two on the right and two on the left side of the mantle, each having its own short nipple-like oviduct which opens into the cloaca, there being two on each side of the anus. The testis is composed of numerous irregularly-lobulated vesicles scattered over the lower portion of the mantle in the vicinity of the posterior extremities of the ovaries, but with which they have no connexion, each separate vesicle having its own short nipple-like duct or *vas deferens*.

The reproductive organs do not exhibit any great diversity in the genus *Molgula*, the ovary and its testis being always combined, and forming one or two elongated masses, in which, however, the two component elements can always be detected by the aid of their colour and structure. The testis is composed of a vast number of branched vesicles or cæcal tubules, crowded together and sometimes assuming a dendritic appearance, while the ovary seems to be a lobulated sac, usually well filled with eggs.

In *M. conchilega* there are two such masses, placed transversely, which are generally irregular in form, but sometimes are broadly fusiform and a little arched. That on the right side of the mantle lies upon the upper border of the intestine; the other occupies the centre of the left side of this tunic. The oviducts are two short tubes; they pass out of the ventral or anterior extremitity of the mass, and open into the cloaca on each side of the intestine. There are four or five long nipple-like sperm-outlets, situated at a little distance from each other along the body of the organ. These open directly into the atrial space on either side of the branchial sac.

A similar arrangement of the genitalia, with numerous short deferent canals, has been described by Van Beneden, in his *Ascidia ampulloides**, which is, there can be little doubt, a *Molgula*. There are two similar genital masses in *M. simplex*; but they are comparatively slender, and are pretty-regularly

* "Recherches sur l'Embryogénie, l'Anatomie, et la Physiologie des Ascidies Simples," 'Mémoires de l'Académie Royale de Belgique,' xx (1847).

fusiform: they are situated exactly in the same way as those in the former species, but that on the right side is overlapped by the looped portion of the intestine.

In an undescribed species [*Molgula complanata*, A. and H.] obtained by the Rev. A. M. Norman in Guernsey, the genital masses are ovate, and are placed as usual, but differ from those of all other species in having the oviducts passing from their dorsal extremities, and consequently turned towards the endostyle instead of being directed to the cloaca. The products of these organs are consequently thrown into the dorsal portion of the atrium, far from the cloaca.

There is only one reproductive mass in *Eugyra arenosa*; it is larger than usual, is of irregular form, and belongs to the right side of the mantle, but overlies to a considerable extent the alimentary tube. The oviduct, as usual, opens into the cloaca; but the *vas deferens* has not yet been observed, though the male secreting-organ is distinctly visible, forming a considerable part of the mass.

In *Clavelina lepadiformis*, one of the Social Ascidians, the genitalia are placed in the loop of the intestine near to the lower extremity of the abdomen, the ovary lying on the right of the alimentary tube, and the testis being spread over both sides of it. The former resembles a bunch of grapes in which the berries are of various sizes; and the oviduct, like the stem of the fruit, is seen in the midst of the ova; and I believe I have traced it passing up the abdomen in the direction of the cloaca, but I did not succeed in determining its outlet. M. Milne-Edwards, in his well-known work on the 'Ascidies composées,'* states that he could not discover how the eggs passed from the ovary to the neighbourhood of the branchial sac, and suggests the possibility of the *vas deferens* acting also in the capacity of an oviduct. This, however, is exceedingly improbable; and, from what I have seen, there can be little doubt of the presence of a true oviduct, although I do not consider my observation a sufficient demonstration of the fact. But there can be no mistake as to the existence of a *vas deferens*; this tube is sufficiently conspicuous; passing up by the side of the alimentary canal, it penetrates the lower wall of the cloaca, and terminates by the side of the anal outlet. The testis is a much-branched organ; the branches are extremely fine, and, dividing dichotomously, terminate in numerous elongated fusiform vesicles, which are united in pairs; or, in other words, the ultimate twigs may be

* 'Observations sur les Ascidies composées des côtes de la Manche,' p. 22.

said to bifurcate, each branch being immediately enlarged, so as to form an elongated cæcal vesicle.

The Blood-System.

The blood-system in the Tunicata is perhaps the most difficult branch in the anatomy to investigate; for these animals are generally too minute and delicate to be successfully injected, and it is not easy to obtain living specimens sufficiently transparent to permit of the blood-current being traced through the tissues. Nevertheless much good service has been done in this way by M. Milne-Edwards and others; but perhaps no one has done more by this method than Dr. Lister, who had the good fortune to meet with a species in every respect suited to the purpose. So far as I have been able to ascertain, the blood-system has been as fully, if not more fully, determined in *Perophora* than in any other Tunicate. It is therefore satisfactory to find that my results perfectly agree with those obtained by Dr. Lister,* so far as they go. This is particularly gratifying, as the mode of investigation adopted by me is very different from that followed by this distinguished anatomist; and, moreover, *Perophora* is one of the Social, while the species used by me are all simple Ascidians.

I have relied almost entirely on dissection, aided by the accumulation of blood-corpuscles in the various parts of the system. In this way the minutest ramifications can be traced with the greatest precision. A vast number of specimens, however, are required; for many individuals may be cut up before one is met with in a proper state. Large specimens, too, are necessary; and they must have the tissues sufficiently transparent, and the blood-globules opaque or coloured; in such only can the blood-channels be distinctly traced. And when the specimens are even in the best condition, many may be opened before the blood-globules are found lodged in the part of the system requiring elucidation. This method is consequently very laborious; but the results are satisfactory; for in such natural injections there is very little danger of being deceived by the blood being extravasated from its natural channels.

Ascidia mentula and *A. venosa* (fig. 4) are good species for this purpose; but the one that appears the best-adapted to this mode of investigation is an undescribed species [*A. plana* Hanc.] closely allied to the former. In this the blood-globules

* Philosophical Transactions,' 1834, p. 375.

are of a brownish colour and very numerous; so that it sometimes happens that in this animal large portions of the blood-system can be traced in a single individual. Most of the information on this portion of the anatomy has been obtained from these three species; but nevertheless several important points have been verified in the living animal.

The blood-system in the simple Tunicates may be looked upon as closed, however limited the true vascular portion of it may be. The blood-channels throughout the organism

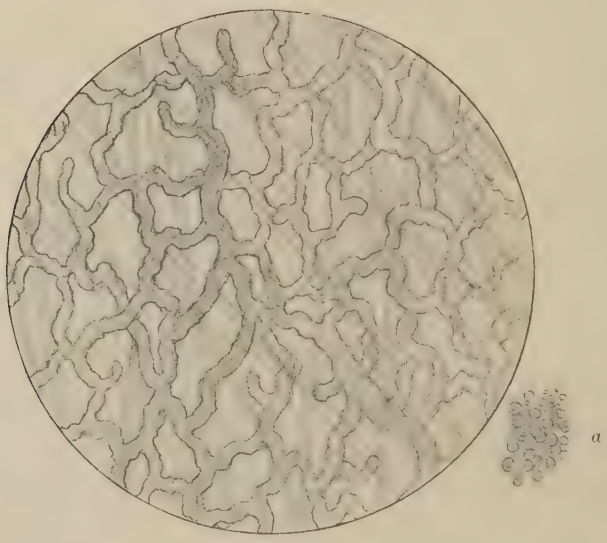


Fig. 4.—Blood lacunæ (curved) and muscular bands (straight) between the mantle and lining membrane of *Ascidia venosa*. Highly magnified. *a*. Blood globules, much more highly magnified, of a reddish-yellow colour and containing a few granules.

are well defined; but whether or not they are provided with proper walls, and, if so, to what extent, is not easy to determine. The trunk channels leading to and from the heart have certainly all the appearance of being true vessels; and the branchial network has likewise the character of being truly vascular. The blood-channels in the test have also distinct walls; but in this case they are apparently composed of a prolongation of the mantle or inner tunic. Traces, however, of an inner vessel may be observed in the main trunks; but this apparent vessel may be nothing more than a continuation

of the lining membrane or "inner tunic" of Huxley. In fact, the so-called vascular ramifications of the test, however minute and divided, ought perhaps to be regarded as prolongations of the pallial cavity, although it is quite possible that they carry true vessels; and, indeed, from the way they are connected with the heart, this would seem almost probable.

The heart (Plate III, fig. 4) is tubular, and is of considerable length. In *Ascidia* it is attached to the lower border of the stomach, one end extending some way up the dorsal region towards the intestinal tube; this may be called the dorsal extremity; the other, the ventral end, points in the direction of the œsophagus. It lies between the mantle and the lining membrane, within a distinct chamber or pericardium, along one side of which it is attached from end to end. The chamber seems as if formed by a fold of the lining membrane; and the heart is probably coated with it in the manner of a peritoneum, and is so attached to the wall of the chamber.

A large trunk vessel passes from the dorsal extremity of the heart, and immediately divides into three branches, one of which advances between the mantle and the lining membrane along the dorsal region at the back of the endostyle; another passes in the opposite direction down the dorsal margin to the bottom of the branchial sac. These two form the great dorsal branchial channel, and are equivalent to the ventral or thoracic sinus of Milne-Edwards; and they both communicate with the dorsal extremities of the transverse channels of the branchial sac. The third branch turns off at right angles to this great dorsal channel, close to the point where it is united to the heart, and, in company with another vessel, to be shortly described, penetrates the mantle and goes to ramify in the test.

From the other or ventral extremity of the heart there are two large trunk vessels given off, one to each side of the stomach. These ramify over the digestive organs and supply a minute network spread over both sides of the visceral mass; this network may be termed the visceral plexus. It is in direct communication with a similar plexus of blood-channels or sinuses that lies between the mantle and the lining membrane of the right side; and this latter is continuous with another plexus similarly situated in the left side of the mantle; these together form what we shall call the pallial plexus. The trunk branch that supplies the left side of the stomach and the portion of the visceral plexus there situated divides into two large stems, one of which inclines towards the intestine, the other towards the œsophagus; the former passes for some

little distance along the intestinal tube, and then, leaving it, penetrates the mantle in the dorsal region, and goes associated with the third branch from the dorsal extremity of the heart, already described, to ramify in the test. Thus originates the double vessel that carries the nourishing fluid to and from that envelope or tunic. The stem that goes towards the œsophagus passes along by the side of the lower extremity of the intestine, and, just before reaching the anus, turns aside to join a large vessel that extends along the ventral margin from one end to the other of the branchial sac (Pl. III, figs. 2 and 3). This, which is the great ventral branchial channel, is the dorsal sinus of Milne-Edwards. It communicates with the ventral extremities of the transverse branchial channels; and its lower extremity bifurcates, a branch passing on each side of the mantle.

The two great branchial channels, the dorsal and ventral, communicate with each other, as we have already seen, by the numerous transverse channels of the branchial sac; they likewise intercommunicate above through a sufficiently obvious channel that encircles the entrance of the sac, immediately above the vascular network, and just below the anterior cord, afterwards described; the lower extremities also appear to communicate with each other by a much-constricted channel. Thus the circle of the blood-apparatus would seem at first sight to be complete; and as the opposite ends of the heart operate upon the two great branchial channels respectively, and as the blood oscillates first in one direction and then in the other, we might look upon the mechanism as sufficiently perfect for all the purposes of the circulation.

But something is still wanting, as is evident when we refer to the fact that the influence of the heart is chiefly confined to the branchial organ, the visceral plexus, and the vascular system of the test. The pallial plexus of the right side is certainly in connexion, as we have seen, with the visceral plexus of that side; but, so far as our examination extends, the plexus of the left side of the mantle is connected with the general system through the minute network of the pallial plexus only. It is obvious that the blood-current would be feeble in these parts, if the whole of the mechanism is now before us. And, moreover, it would be most languid in the left pallial plexus—in that very portion of the mantle, in fact, that is most amply supplied with muscular fibres, and which, being comparatively free, has undoubtedly the greatest mobility. Indeed, unless some additional means exist to aid the circulation, engorgement of the blood-channels must in-

evitably take place in the pallial plexus when the heart pulsates in the direction of the viscera; and when its action is reversed, exhaustion would ensue in this portion of the system.

Now, though the branchial sac is attached to the walls of the pallial chamber in front and behind and along by the dorsal margin, it is necessary that the lateral or reticulated portions of the organ should be suspended, and in such a manner as to leave a considerable space between the sac and the pallial walls. Consequently a number of suspenders are provided, which, while they retain the branchial sac in its proper position, allow the required space. These suspenders are in the form of cylindrical bands or ties, and are contractile; they pass from the transverse branchial channels and from the great ventral channel to the walls of the pallial or respiratory chamber; they are hollow or tubular, and are the means of communication between these blood-channels and the pallial plexus of both sides, and also with the visceral plexus of the left side. Thus the blood-currents in every part of the organism are brought under the influence of the heart. One of the suspenders, larger than the rest, connected with the ventral branchial channel, opens into a considerable channel or sinus in the mantle in which the nervous ganglion is placed; and the vessel which carries the blood from the heart to the great branchial channel has also much the character of a suspender.

There can be no doubt whatever of the fact that the branchial suspenders are tubular, and that they carry the blood, as above stated, from the branchial network to the visceral and pallial plexuses. I have seen in several instances the channels in the suspenders gorged with blood-corpuscles, as well as the channels connected with them in the pallial and visceral plexuses, and the transverse channels of the gill-sac; and thus by such natural injections the fact has been demonstrated over and over again. And, moreover, I have witnessed blood-corpuscles pass through the channels in the suspenders in young living individuals of *Ascidia sordida*.

When the heart acts in the direction of the dorsal extremity, the blood will at once be thrown into the dorsal branchial channel, and will pass by the dorsal trunk of the compound vessel into the test; all the transverse channels of the branchial sac will be filled; and through the agency of the suspending tubules or vessels the pallial plexuses of both sides of the mantle, as well as the visceral plexus of the left side, will be supplied in all directions; while that portion of the blood-current which is retained in the vascular reticu-

lation of the branchia will be hurried into the great ventral channel, and by this to the ventral extremity of the heart. But before it reaches so far it will be joined by the streams derived from the visceral plexuses of both sides of the body, and in this way with that from the pallial plexus, chiefly, of the right side. The greater portion of the blood from the left side of the mantle will reach the heart by the ventral branchial channel, having been brought hither by the suspenders. The blood thus returned will likewise have commingled with it that which is drained from the vascular system of the test by the ventral trunk of that system. It is thus apparent that the blood which arrives at the heart in this direction is only a partially aerated current.

When the action of the heart is turned in the opposite direction, just the reverse of all this takes place. The blood-current will now fill, in the first instance, the visceral plexuses of both sides, then the right pallial plexus; at the same time it will reach the great ventral channel of the branchial sac, and through it the transverse branchial channels; while simultaneously the blood will be pushed into the left pallial plexus through the suspenders placed along the ventral channel. The blood that now enters the vessels of the branchial sac will be joined by numerous streamlets issuing from the suspenders, and brought by them out of the visceral and pallial plexuses, and will ultimately arrive in the great dorsal channel, and so to the dorsal extremity of the heart, at which point it will be mingled with the current from the test brought by the dorsal branch of the compound vessel ramifying in that tunic—the trunk, in fact, which in the first instance carried the blood to the test. Here, then, as well as in the former case, the current returned to the heart is only in part aerated; but the aeration is undoubtedly more complete when the stream sets in this direction than in the other; for now the only unaerated portion is that from the test, while in the first case the blood from the visceral and pallial plexuses is likewise in a partially aerated condition.

The pulsations of the heart appear to vary considerably in number even in the same individual; and the numbers of the oscillations in the same direction seem never exactly to agree; neither is there any constancy as to whether the dorsal or the ventral oscillation has the greater number. In a young individual of *Ascidia sordida*, in which the movements of the heart were carefully observed, the pulsations were counted four times in each direction, and the following was the result. On the first occasion there were 73 beats in the ventral direc-

tion, 70 in the dorsal; on the second, 64 ventral, 68 dorsal; on the third, 74 ventral, 88 dorsal; and on the fourth, 63 ventral, and 64 dorsal. It required $2\frac{1}{4}$ minutes to accomplish the beats during a single oscillation. In another individual of the same species, considerably larger than the former, but still quite immature, there were 138 pulsations in one direction, and 120 in the other. Two or three of the concluding beats of each oscillation were not so vigorous as the rest; and when the action was about to change, a dead pause ensued of about two seconds.

In *Polyclinum aurantium* the pulsations were found to be 112 in one direction and 115 in the other; and on starting, the beats were slow. They afterwards became rather rapid, and before ceasing were again retarded; the action then stopped for a second or two before recommencing in the opposite direction. The pulsations in *Botrylloides radiata* are nearly as numerous as they are in the last species. In one individual 102 beats were counted in the one direction, and 115 in the other.

The above account of the circulation will be found to agree with Dr. Lister's description of it in *Perophora*, so far as it was determined in that form; but that excellent observer did not detect the flow of the blood through the suspenders, although "filaments" attaching the branchial sac to the mantle are described and figured by him. Their function as blood-carriers seems equally to have escaped detection by Van Beneden, though he must have been aware of their existence as bands or ties; for they were figured by Savigny, who described them as ligaments attaching the branchia to the inner tunic,* and they are well known to anatomists generally. Van Beneden, however, discovered the necessity of a passage for the blood-current from the "periintestinal cavity" to the branchia to prevent engorgement when the pulsations of the heart were continued for any length of time in one direction. He therefore believed that the required communication was effected through the agency of the "respiratory tentacles"†.

It will now, however, be of no avail to discuss the improbability of such an opinion, since ample communications have been demonstrated. But it may be remarked that these tentacles are undoubtedly hollow, and that in each there is a double channel, that the blood will assuredly pass up one of them and down the other, and that it will oscillate in unison

* 'Mémoires sur les Animaux sans Vertèbres,' pt. ii [p. 97, pl. vi, f. 4; pl. vii, f. 2].

† *Op. cit.* [on p. 31], p. 113.

with the movements of the heart. In fact, Van Beneden states that he has seen it do so. I have observed nothing to warrant the belief that either of the channels is in immediate communication with the vascular network of the branchial sac. On the contrary, they both seem to me to open into the pallial plexus, which of course is continued into the wall of the inhalant tube.

The blood-system does not appear to vary much in the Tunicata; though certainly I have not traced it in the other genera so completely as in *Ascidia*, yet enough has been seen to warrant the above assertion. The heart is very similar throughout all the various forms examined; but its position is not by any means constant. In *Corella parallelogramma* it is placed on the anterior margin of the stomach, and in connexion with the left side of the mantle or inner tunic, following the removal, in this instance, of the visceral mass from the right to the left side. In *Ciona intestinalis*, in which there is developed an abdominal chamber, it is doubled upon itself, and lies in this chamber towards the dorsal margin and between the stomach and the bottom of the branchial sac. The heart in *Styela* is very long, and narrower than usual; in this form it lies between the inner tunic and lining membrane on the left, and a little way from the posterior extremity of the mantle, following the curvature of, but at some little distance from, the alimentary tube. The posterior extremity opens into the dorsal branchial channel a considerable way up the endostyle; the ventral extremity is attached to the stomach, to either side of which it gives a branch in the usual manner. In *Pelonaia* the heart is likewise in connexion with the left side of the mantle, and in other respects resembles the arrangement in *Styela*. And in *Molgula* it holds much the same situation—but is placed between the reproductive mass which is above it, and a hollow cylindrical body with hard walls, the nature of which is not understood.

The branchial sac is usually more complicated than is generally supposed. Hitherto its mechanism has been spoken of in this communication only so far as was necessary to the full comprehension of the blood-system; it is now time to say something respecting its more minute structure. In all the Tunicates there must of necessity be present the two great branchial or thoracic channels (the dorsal in connexion with the endostyle, and the ventral at the opposite side of the thorax), even when the branchial sac is only partially or not at all developed; and in every instance where a true gill is present the transverse channels or primary vessels must also

exist. These latter may be considered the essential or elementary parts of the respiratory organ; the minute details, consisting of secondary vessels, are variable, even in very closely allied species, and are not always present.

The simplest form of the organ that occurs in the genus *Ascidia* is found in *A. venosa* (Pl. X). In this species the transverse or primary vessels, or channels, are placed at regular intervals, and scarcely vary at all in size; and between and opening into them at right angles are numerous small, longitudinal, secondary vessels divided by elongated spaces or stigmata; so that the whole forms a reticulation of vessels in which the transverse channels are large and distant, the longitudinal ones small and numerous and divided only by narrow open spaces. Or the structure may be described, for convenience, as it frequently is, as a vascular membrane with large transverse channels and minute longitudinal ones connecting the former, and divided by narrow elongated stigmata. This is the true aerating surface of the gill; and were there no additional appendages, the organ would appear to be composed of numerous transverse series of short longitudinal vessels and narrow openings divided by large transverse channels or vessels; it would appear to be, in fact, what it essentially is. But on first inspection, with the aid of a low magnifying-power, it seems to be formed of a comparatively coarse reticulation of longitudinal and transverse vessels of nearly equal size, crossing each other at right angles, and having four or five narrow longitudinal openings or stigmata in each square mesh, dividing as many minute vessels.

This appearance is produced by the existence of a number of stout so-called longitudinal vessels or bars that extend from one end to the other of the branchial sac, and project considerably from the inner surface of the organ, to which they are attached only at the points where they cross the transverse channels. Here they are supported upon short wide pedicles through which they receive their supply of blood from these channels; they are thus lifted some little distance above the general surface of the gill. At these points the longitudinal bars are a little enlarged, and have on their upper margin a stout elongated papilla with the extremity rounded. There is thus a papilla at the angles of each mesh; and they are all inclined towards the ventral side of the respiratory sac, and have on the upper surface, and in front, an elongated disk which is apparently ciliated.

The walls of the longitudinal bars are comparatively thick; and hence these organs have a certain degree of rigidity. It

is not very easy to determine of what use they are; but perhaps their chief function is to protect the more delicate tissue of the true aerating vascular surface; while the papillæ will conduce to the same end, and by the aid of their cilia probably sweep the sedimentary matters towards the oral lamina, the water being beat through the stigmata by the cilia that fringe their borders. From the stiffness of the bars themselves it may be inferred that they will also give support to, and keep stretched out, the vascular network of the sac. They seem ill calculated, on account of the thickness of their walls, to give much assistance in aerating the blood, and are certainly unnecessary as part of the circulatory mechanism.

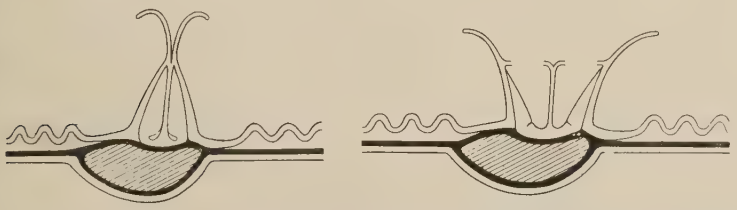
The blood, as we have already seen, is brought to and taken from the aerating reticulation by the dorsal and ventral branchial channels, and by numerous suspenders connecting it with the visceral and pallial plexuses. We have also traced the blood through the principal channels of the organ from one side of it to the other. All, therefore, that remains to be done is to follow the flow of the stream through the minute portions of the structure.

The extremities of the heart, we have seen, do not open into the ends of the two great branchial channels, but a considerable way above their lower terminations. It is consequently evident that the blood will move upwards in these channels above the point where it enters, and downwards below it; and when we consider the action of the current so brought to the transverse channels, it is clear that the flow will be in contrary directions in the small longitudinal or secondary vessels above and below this point. Now, it has been already stated that on the reversal of the action of the heart there is a pause of a second or two, so that for this period the currents cease to move and the fluid becomes perfectly stagnant. On resuming its function, the first act of the heart is to dilate; consequently, the blood is drawn towards it from the respiratory organ; and it follows, as a matter of course, that the fluid in the secondary vessels above the point just alluded to in the great branchial channels must flow downwards, and in those below this point upwards. This will be the case whether the blood is brought to the branchial sac by the dorsal or the ventral channel. Such downward and upward set of the blood-current in the secondary vessels has actually been observed in *Perophora* by Dr. Lister, who states that "the horizontal vessels were connected also by the smaller or vertical channels between the spiracles—the set of the current in the latter being upwards for the two

lower rows, and downwards for the two upper rows." If the heart in the first instance threw the blood into, instead of drawing it from, the gill, the reversal of this motion would take place; namely, the flow in the secondary vessels above the point indicated would be upwards, and downwards below it.

Such are the characters of the branchial sac as seen to exist in *A. venosa*. The minute network, however, is not continuous throughout the whole organ, but is interrupted in such a manner as to show that it is composed of two lateral lobes or laminæ. It is divided along the dorsal line by two parallel folds of the lining membrane, which are separated by a deep groove; the tissue at the base of each fold is stiffened by a flattened rod of a somewhat rigid, opaque, yellowish substance, which together form the endostyle, that lies, as it were, in the bottom of the groove, along which the

Fig. 5. Fig. 6.



Figs. 5 and 6.—Transverse sections of the endostyle of *Ascidia mentula*, highly magnified. The shaded portion represents the dorsal blood-sinus, the thick black line the endoderm. Fig. 5, before separation of the lips. Fig. 6, after separation.

rods appear to be united (see Pl. III, fig. 5, and figs. 5 and 6 in text). The upper extremities of these folds diverge right and left, and become continuous with the lower member of what may be termed the anterior cord or collar—two narrow folds also of the lining membrane that encircle the base of the respiratory tube, a little above the anterior margin of the branchial sac, and having the circular blood-channel, previously mentioned, immediately below them. The ventral margin of the sac is furnished with a wide, longitudinal, delicate, membranous fold, which apparently also orginates in the lining membrane, and which interrupts the continuity of the minute network in this direction. This is the ventral or oral lamina (Pl. XIX); it extends from end to end of the branchial sac, and is ribbed transversely; the margin is entire. The mouth opens close by its left side, about one-third from the lower extremity: the upper extremity for some little way downwards is divided longitudinally, showing that the lamina

is really composed of two lateral membranes; and each division is united to the lower member of the anterior collar, much in the same manner as the latter is attached to the dorsal folds connected with the endostyle. The upper member of this collar is divided from the lower by a narrow groove, and is uninterrupted by either the oral lamina or the dorsal folds. The oral lamina is connected below by another narrow cord to the posterior extremity of the dorsal folds: this is the posterior cord.

In this way are traced the boundaries of the two lateral laminæ composing the branchial sac. They are attached by their upper borders to the walls of the pallial or respiratory chamber a little below the anterior collar or cord; the dorsal margins are attached along the sides of the endostyle, and the lower margins along the line of the posterior cord. In all other parts the two lobes are free, except at the points where the suspenders bind them to the walls of the chamber, and where the extremity of the œsophagus penetrates the branchial sac; and here, of course, the latter is attached to the alimentary tube. The supposed function of the endostyle has been already indicated; the folds of the lining membrane to which it is adherent are no part of the gill: neither can the oral lamina be considered a portion of the breathing-organ: it is certainly highly vascular; that is, minutely ramifying blood-channels can be traced in it: but similar vessels (or channels) are seen in all the membranes of the organism, and also occur in the dorsal folds in connexion with the endostyle. The office of the oral lamina is to conduct the food to the mouth. And it has already been stated that the sedimentary matters are there accumulated and formed into a cord, and so carried to the oral aperture along the lamina. The anterior cord may perhaps also aid in collecting sedimentary aliment, if it be ciliated, as its homologue in *Salpa* is stated by Professor Huxley* to be.

The simple form of gill above described is not by any means constant in *Ascidia*; in fact, it seems but rarely to occur in this genus. The same simplicity of structure, however, is found in *Pelonaia*, with only some unimportant changes. In *Clavelina* and *Perophora* the vascular network is not more complicated; and in the former, at least, the longitudinal bars have entirely disappeared. And in it there are numerous transverse laminæ which are adherent throughout to the walls of the transverse channels; they are united to the filaments of

* "Observations upon the Anatomy and Physiology of *Salpa* and *Pyrosoma*," 'Phil. Trans.,' 1851, pt. 2, p. 567.

the oral lamina, and perhaps are mainly instrumental in carrying the food in that direction. The structure of the gill is equally simple in the compound Tunicates; and in them the longitudinal bars seem to be occasionally present.

In *Ascidia mentula* and *A. sordida* the branchial network is fundamentally the same as in *A. venosa*; but in the two former, and in some others [*A. scabra* and *A. affinis*, &c.], it is minutely folded longitudinally, so that, on making a transverse section of it, the edge presents a deeply undulated line. The surface is not altogether unlike corduroy; it is, in fact, finely plaited (or crimped, as the laundress might say); but the flutes or grooves between the ridges or plaits are interrupted wherever the transverse vessels cross them, the vessels at these points filling up the hollows. Thus there are numerous septa formed, turning the grooves into series of minute recesses or pouches.

The longitudinal bars are strong and raised considerably above the inner surface in *A. mentula*; and there are smaller intermediate papillæ, as well as larger ones at the points where the bars cross the transverse vessels. All the papillæ bear ciliated disks: and a wide membrane stretches from the back of the larger papillæ for a considerable way along the transverse vessels. In *A. sordida* the bars are likewise strong; but the papillæ are rather small, and there are no intermediate ones. Between the longitudinal bars there are two oval ciliated disks, one on either side of the middle line of the transverse vessels.

The oral lamina in *A. sordida* is a wide plain membrane; but in *A. mentula* it is strongly ribbed transversely, and the ribs, passing beyond the margin as fine points, give to it a pectinated appearance.

In *Styela tuberosa* and its immediate allies we have another modification of the branchial network. In them it is provided with eight simple longitudinal folds or laminæ—four on each side of the oral lamina; these stretch from one end of the sac to the other, and terminate below by the sides of the oral orifice. The network is, in other respects, as simple as it is in *A. venosa*, there being no minute plaiting such as is seen to exist in *A. mentula*. The folds, however, give to it a very interesting character, inasmuch as we observe in them a very ready and efficient mode of increasing the aerating surface, as, indeed, the same end is gained by the minute plaits in the vascular network in *A. mentula* and *A. sordida*. In *Styela* the folds are formed in exactly the same way as those minute plaits; that is, they are each composed of a fold of the branchial sac,

and the space within is divided into pouches by septa situated at nearly equidistant points. In this genus the transverse vessels vary considerably in size, there being usually one or two smaller between the larger ones; and the septa are placed wherever the latter cross the structure. Thus a series of pouches of nearly equal size occupy the interior of the folds, and open at the outer surface of the branchial sac into every part of the atrium. In fact, we see here an arrangement very similar to that observed in the interbranchial water-channels in the Lamellibranchs; and in this case, as in them, the purpose is to allow the water, after permeating the walls of the fold or lamina, to escape externally.

The longitudinal bars in *Styela* assume the form of delicate ribbon-like membranes attached by one edge to the principal transverse vessels; they are numerous, and are found on the folds as well as on every other part of the organ. The oral lamina is a wide simple membrane.

The branchial sac in *Mongula conchilega* and its allies is characterized by longitudinal folds or laminæ, formed much in the same way as those in *Styela*. In the former there are six such folds on each side of the sac. The vascular network, however, is very different, having the secondary vessels, or those which are usually arranged at right angles to the transverse channels, disposed in imperfect spiral coils or convolutions, the vessels themselves frequently intercommunicating; consequently the stigmata or open spaces separating them are broken into various lengths. There are also a few delicate radiating vessels which pass from the centre of the coils to the circumference, but mostly in the direction of the transverse channels that convey the blood to and from the coils. The chief purpose of these radiating vessels is apparently to prevent engorgement of the coil, and to aid the reflux of the stream by conveying the blood in the most direct manner to and from the centre of the coil. When the spiral arrangement is more imperfectly developed than usual, the radiating vessels are very irregularly dispersed; but even in such cases there can be little doubt that their function is as above stated. The longitudinal bars have the ribbon-like character of those in *Styela*, and are principally confined to the folds.

Corella parallelogramma has also the secondary vessels spirally arranged, as originally pointed out by Mr. Alder*; and here the coils, which form slight conical eminences,† are

* "Observations on the British Tunicata," 'Ann. Nat. Hist.,' ser. 3, xi, p. 158.

† [*Op. cit.*, pl. vii.]

disposed in regular transverse series between the transverse channels. The coiled vessels do not so frequently intercommunicate as they do in *Molgula*; consequently the stigmata are much longer, being less interrupted. The radiating vessels are not numerous, and they pass from the centre of the coil to the transverse channels. The longitudinal bars are more rigid and cord-like than usual; they project considerably from the surface of the gill; and the papillæ which are attached to them are not elevated, but inclining backwards are united throughout their length, and give support to wide membranes that extend from the surface of the transverse vessels. In this species the oral lamina is replaced by a series of well-developed filamentous processes.

The most perfect, however, of the spiral type of gill is found in *Molgula arenosa*. In this interesting species the interior of the branchial sac is furnished on each side with six or seven wide, longitudinal, ribbon-like bands, which are attached by

Fig. 7.—Tentacles of *Ascidia Alderi*. Highly magnified.

one edge to the transverse vessels at the points where they cross them. These bands, how like soever in general appearance, are not to be confounded with the branchial folds in *Styela* and *Molgula*; they are the homologues of the longitudinal bars so constantly present, and with the transverse vessels give to the surface a coarse reticulation, the square meshes of which are each occupied by a conical eminence. On account of the prominence of the longitudinal bands these eminences, which look like so many miniature beehives, seem to be arranged in six or seven longitudinal series. Each cone is formed of a double spiral coil of secondary vessels united at the apex; the coils are perfect, and the stigmata, which are coextensive with them, appear to be scarcely, if at all, interrupted by intervascular communications. Radiating vessels, however, which are sufficiently numerous to prevent engorgement, pass from the apex of each cone to the transverse vessels, and are the principal interruptions to the continuity of the spiral stigmata. The oral lamina in this, as in all the members of the genus, is a plain simple membranous band.

All the simple Ascidians that have come under my notice, not even excepting *Pelonaia*, have a collar of tentacular filaments situated at the base of the incurrent tube, some distance above the entrance of the branchial sac (Pl. III, and figs. 7–9 in text); indeed the distance in some species is considerable,

Fig. 8.—Tentacles of *Ciona fasciculatis*. Highly magnified.

and no instance has occurred in which they could be said to be connected with the gill. They are usually linear or slightly conical, and are rather numerous, except in *Pelonaia*, which has not more than twelve or fourteen; but in *Molgula* and in some of the other *Cynthiadæ* they are branched or pinnate,

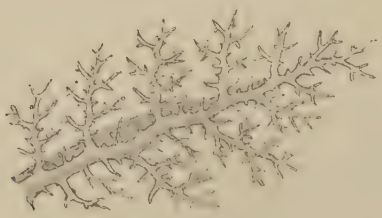


Fig. 9.—A tentacle of *Cynthia echinata*. Highly magnified.

and are not very abundant. They, however, all agree in being soft, delicate, hollow organs; and the simple ones, at least, have the interior divided by a septum into two longitudinal channels, so that the blood will circulate freely through them [as seen in fig. 7]. They appear to be an outgrowth of the lining membrane, and are supplied with blood

from that which flows between it and the mantle or inner tunic.

The Branchial Tubercle and Nervous System.

That enigmatical organ the branchial tubercle (the anterior tubercle of Savigny) (Pl. XX) is situated in the space between the tentacular filaments and the anterior margin of the branchial sac, in contact with the upper membrane of the anterior cord or collar, and immediately in front of the upper extremity of the oral or ventral lamina. It is formed of two parallel folds of the lining membrane pressed close together and united at the extremities; they seem but as one fold, and are bent into a loop with the ends turned towards the inhalant orifice, and, inclining inwards, are a little convoluted. Thus the organ assumes a rounded or oval form, rising above the surface to which it is attached as a depressed compact tubercular swelling. An opaque white line marks the separation of the two folds, and follows the convolutions to the extremities.

This is the form that this curious tubercle assumes in *Ascidia scabra*, *A. affinis*, a closely allied species, *A. mentula*, and *Pelonaia corruguta*. In *A. sordida* one of the extremities turns inward, the other outward, so that both are bent in the same direction. But more striking modifications occur in some other species. In one allied to *A. mentula* there are three loops, crowded upon each other, and having their extremities only slightly incurved; and in another closely related form the organ is dense, large, and somewhat quadrangular, with numerous irregular convolutions formed apparently of several loops of the lining membrane. In *Styela tuberosa* and *S. mamillaris* it is large, oval, and disk-like, with the extremities so indistinct as to be scarcely traceable. The reverse of this is the case in *Molgula conchilega*, in which it is almost crescent-formed, with the extremities very obvious and well turned inwards. And in *Ascidia venosa* it is still more simplified, being a mere horseshoe-like loop, with the extremities pointed and very slightly incurved.

It is not easy to assign a function to this peculiar organ—though, from its position at the entrance to the branchial sac, it may be inferred that it is of the nature of a special sense, testing the quality of the inhaled water. Taste could be of little use to an animal which has not the power of selecting its food; but it would seem necessary for the creature to be warned of the approach of aught deleterious in the respiratory currents. The function of this organ is therefore probably more akin to that of smell than of taste. It is certainly

of some importance in the economy of the animal; for it is constantly present, and is usually closely associated with the ganglion. In some species the tubercle rests upon the nervous centre; and when placed at a little distance from it, a nerve may generally be traced running towards (and in some instances having all the appearances of supplying) it.

The nervous system is in a very rudimentary condition in the Tunicata. There is but one ganglion; and it is invariably placed between the two respiratory tubes, in a blood-sinus situated between the inner tunic and lining membrane, which

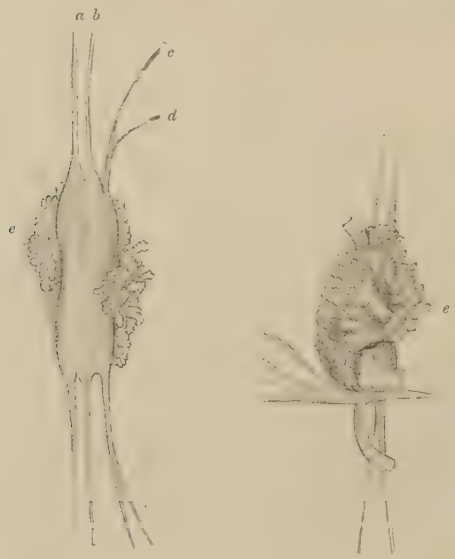


Fig. 10. Fig. 11.

Figs. 10 and 11.—The nerve-ganglion in *Ascidia mentula*. Fig. 10, as seen from the outside of the mantle. Fig. 11, as seen from the inside of the mantle. *a* and *b* lead to incurrent tube, *b* subsequently dividing, and one branch going to ventral side of tube. *c* and *d* lead to mantle. *e*, gland-like organ. Highly magnified.

sinus, communicating directly with the great ventral channel of the branchial sac, will be well supplied with aerated blood. The ganglion is fusiform, more or less elongated in the antero-posterior direction, and usually a little constricted in the middle, as if composed of two centres (figs. 10 and 11). In *A. mentula*, and in several other species that have been examined, it is partially folded in a much folliculated gland-like substance, and gives off from each extremity three or four nerves, all of which go to the respiratory tubes and to the

adjacent portions of the inner tunic or mantle. A branch from one of the principal nerves has been traced to the branchial tubercle in one or two species. There is no variation of any consequence in the nervous element in any of the forms examined.

Salpa and its Relationship with other Tunicata.

The organisation of *Salpa* is highly instructive; for in this form we have a Tunicate in which development has been arrested, and which, to a certain extent, has an embryonic character. In it the branchial sac is entirely absent, and the circulatory system is in much the same condition as it is in the young of *Ascidia* before the respiratory organ is developed.

In *Salpa* the outer tunic or test appears to be quite free from the inner tunic or mantle, except at the margins of the anterior and posterior orifices, where they seem to be united. The inner tunic and lining membrane, or that which forms the inner wall of the respiratory cavity, are, on the contrary, adherent throughout, spaces only being left for the passage of the blood-currents; for it is between this tunic and membrane that the "sinus-system" is situated. The respiratory cavity corresponds pretty accurately to the pallial chamber of a simple Ascidian—were the branchial sac entirely removed, leaving only the endostyle with its two lateral folds, the ventral or oral lamina, and the connecting cords.

On examining the great respiratory chamber or cavity in *Salpa spinosa*, for instance, an endostyle with the two lateral membranous folds, similar in all essentials to that organ in the other Tunicata, is seen adhering to the dorsal wall of the cavity; and the so-called "branchial band" or "gill" is conspicuous on the opposite side, passing forward from the nucleus in an inclined position, the posterior extremity being attached in the vicinity of the mouth, the anterior to the ventral wall of the cavity. The two folds in connexion with the endostyle and the "branchial band" are connected in front by a narrow band (the "ciliated band" of Huxley) that encircles the anterior extremity of the respiratory cavity: and another similar band, or pair of parallel bands, passes from the posterior end of the dorsal folds and terminates near to the posterior extremity of the "branchial band." Thus we observe certain lines or bands which, together with the endostyle, correspond to the boundary lines of attachment of the branchial sac of a simple Ascidian; and if we

suppose a vascular network extended from either side of the endostyle to the lateral margins of the "branchial band," and imagine it to be attached in front and behind along the ciliated bands, we shall see how readily a Salpa may be made to assume the most striking feature of an ordinary Ascidian.

Now the ciliated bands are the homologues of the posterior cord and the lower member of the anterior cord or collar of the branchial sac of the simple Ascidians; and the "branchial band" is the equivalent of the oral or ventral lamina of the same group. The relation of the ciliated bands, particularly the anterior, to the "branchial band," and the characters of the latter, sufficiently prove this.

The so-called branchial band has the appearance of a cylindrical tube; but it is easily seen that it is formed of two laminæ, the lower or ventral margins of which are a little separated, while the upper or dorsal are brought together, forming a ridge along this margin. A large blood-channel runs along in connexion with, and immediately below, the ventral margins; this is the homologue of the ventral branchial channel. The two laminæ rise, as it were, from the sides of this channel, and inclining towards each other, are united along the dorsal ridge as just stated; but towards the anterior extremity of the organ they separate, and become united to the ends of the ciliated cord or band in exactly the same way as the lateral divisions of the oral lamina join the anterior cord or collar. In fact, in both *Salpa* and *Ascidia* the one organ seems to be a continuation of the other, as they are, no doubt in both, productions of the lining membrane, the blood-channel itself being developed in connexion with the same membrane. The "branchial band," we thus see, corresponds to the oral lamina in being composed of two laminæ, in its relation to the anterior ciliated band or collar, and in its connexion with the great ventral blood-channel. And, moreover, like the oral lamina in several of the *Ascidiæ*, it is transversely ribbed. In *Salpa* the ribs are stout and strongly ciliated; and there can be no doubt that they are also ciliated in *Ascidia*.

In *Salpa*, then, the so-called branchial band cannot be looked upon as a true gill; and homologically it does not represent the branchial sac at all, but only that appendage of it the oral lamina. And as the function of the latter seems to be chiefly, if not exclusively, to carry the food to the mouth, the same office is probably performed by the so-called gill in *Salpa*. And, indeed, without some such help it is difficult to see how such an animal would be able to take its food. There can be little doubt that the walls of the respiratory cavity, as

has been suggested by Professor Huxley*, chiefly effect the decarbonization of the blood; while this so-called gill will aid in this operation in proportion to its vascularity; as must, indeed, all the tissues bathed by the respiratory currents.

The ganglion lies on the ventral side of the respiratory cavity, between the lining membrane and inner tunic, a little in advance of the ciliated band, and directly in front of the anterior extremity of what we may now term the oral lamina (the pseudo-gill). All the nerves are given to the walls of the cavity—in other words, to the inner tunic or mantle. The anterior extremity of the ganglion is produced a little, giving an appearance to the organ as if composed of two centres. On the anterior surface of the produced extremity there are three or four imperfectly formed black pigment specks, having the appearance of rudimentary eyes, which, however, Professor Huxley considers to be auditory capsules.

The "languet," with its ciliated "fossa," is placed just in front of the ganglion, consequently on the same middle ventral line with it and the oral lamina; it is a long, tapering, conical process, with a longitudinal groove which widens at the base where it joins the fossa, over which it seems to straddle. There can scarcely be any doubt that this is an organ of special sense; and it would appear probable that its office is to ascertain the quality of the respiratory currents, and may therefore be olfactory. Thus in function the "languet" would seem to agree with the branchial tubercle so constant in the other Tunicates [with the apparent exception of *Ascidia mamillata*, in which it is inconspicuous]; but it is, moreover, homologically speaking, the same organ, as appears demonstrated by its position in relation to the ganglion, the ciliated band, and the pseudo-gill. Like the tubercle, too, it is a production of the lining membrane; and, as indicated by the longitudinal groove, like it, also, the "languet" is probably formed of two portions or folds of this membrane. It must, therefore, not be confounded, as it frequently has been, with the tentacular filaments of the oral lamina in *Clavelina*, *Pyrosoma*, and several other simple and compound Ascidians.

The homologies, however, do not stop here; the clear anastomosing vessels or tubes ramifying over the surface of the intestine, described and figured by Prof. Huxley,† and supposed to "represent a hepatic organ," or "a sort of rudimentary lacteal system," are, there can be no doubt, the homologue of the rudimentary liver before described in *Ascidia* and in

* "Anatomy and Physiology of Salpa and Pyrosoma," 'Phil. Trans.,' 1851, pt. 2, p. 570.

† *Loc. cit.*

some of the Cynthiadæ; and, indeed, the structure appears to resemble very closely that of the hepatic organ in *Corella parallelogramma*. The "mass of clear cells," the "elæoblast" of Krohn, according to Huxley, may perhaps prove to be the same as the well-known cell-structure before described as coating the alimentary tube in the *Ascidiæ*; but this is mere conjecture.

Thus we see how close the relationship is between *Salpa* and *Ascidia*; with *Clavelina*, however, the connexion is still more intimate. This is undoubtedly a near ally; it is only necessary to look to immature specimens to be satisfied of this. When the young *Clavelina* is about one twentieth of an inch long, and when the thoracic portion would scarcely be half that length, the thorax is remarkably like the embryo of *Salpa*. In profile both have a subtriangular form, the anterior opening being placed at the angle in front, and the posterior at an angle situated considerably backward, the young of *Clavelina* having the two orifices nearly as far apart as they are in the embryo of *Salpa*. At this early period of growth the endostyle is distinctly developed in both forms, and the ganglion and the oral lamina are clearly indicated, also the ciliated band or anterior collar. So far, everything is alike; the general similarity of the respiratory cavity is obvious enough; and were the nucleus in *Salpa* produced a little more than it is backwards, the resemblance of the two would be almost complete. But in the young of *Clavelina* there are, in addition to what has already been described, the tentacular filaments of the incurrent tube, which are now of considerable size; and the branchial sac has already commenced its development.

The latter organ, however, is in an exceedingly rudimentary condition: only a single transverse channel or primary vessel on each side of the great ventral channel has made its appearance, and does not yet extend much more than halfway across the thoracic or respiratory cavity, on its way (so to speak) to the dorsal channel in connexion with the endostyle. On each side of these growing primary vessels five or six secondary vessels, at right angles to them, have commenced to sprout; and the distal extremities of all of them, as well as of the primary vessels themselves, open through the lining membrane of the thoracic cavity into the sinus-system between it and the inner tunic. Thus is defined, on either side, the nascent atrium, which is only an extension of the cloaca that had been previously formed. Shortly another primary vessel makes its appearance, extending from the ventral channel and connected laterally with the extremities of the secondary vessels already

formed; and then another series of secondary vessels is developed, and afterwards another primary vessel, and so on, gradually increasing the length of the two branchial leaflets (if they may be so called), which at the same time grow in breadth, passing further and further across the thoracic cavity until at length they reach the sides of the endostyle; all the while the primary and secondary vessels along the margins of the growing organ, open into the pallial sinuses in the manner already indicated; so that the boundary of the water-space or atrium is well defined, and is always coextensive with the expanding gill. The oral processes, which in this animal occupy the place of the lamina, are produced one by one, in accordance with the appearance of the primary vessels; and the vascular suspenders likewise originate at the same time.

It is unnecessary on this occasion to trace the development of the branchial sac further, or with more minute details; it should be observed, however, that the growth of the gill undoubtedly originates in the great ventral channel, which is itself a production of the lining membrane, and that during the development of the organ it is connected with this membrane, and that this connexion is ever afterwards maintained by the vascular suspenders. It may also be remarked that in no stage of the growth is the gill ever connected, on the one hand, with the margin of the oral orifice—or, on the other, with the tentacular filaments of the incurrent tube, which are, indeed, placed at a considerable distance from the upper margin of the gill; and the lower margin is some way above the oral orifice.

The above description of the development of the gill does not exactly agree with that given by A. Krohn of the branchial sac of *Phallusia* (*Ascidia*) *mamillata**. According to this author, there are at a very early stage of development two excurrent orifices, one on each side of the middle line,—necessitated by the fact that the gill commences to separate itself from the walls of the cavity at two points simultaneously, thus forming two separate water-spaces, one on each side of this line,—the great ventral blood-channel apparently not being yet detached from the inner tunic. It is not till the "branchial sac is everywhere perforated" that these water-spaces, according to this naturalist, are united by the formation of the cloaca. I have certainly not seen the young of *Clavelina* in a sufficiently early stage of development to warrant the assertion that such does not take place in this form; but assuredly

* "On the Development of the Ascidians," by A. Krohn, 'Scientific Memoirs,' edited by Henfrey and Huxley, 1853, p. 324.

in it, at a very early period, the cloaca freely communicates with the water-space or atrium on each side. At the same time it must be allowed that it is more than probable that, at the earliest stage of existence, in *Clavelina* and in other Tunicates the great ventral channel is united throughout to the wall of the pallial chamber; and hence the statement of Krohn does not seem at all unlikely. And, moreover, we thus learn that this great blood-channel is developed in connexion with the lining membrane, with which it continues ever afterwards more or less connected. We have already seen that the transverse or primary vessels take their origin in this same vessel, and that they in their turn give off the secondary vessels: these are the essential parts of the branchial tissue, and when we look to its anatomical structure as well as to its mode of growth, we can scarcely doubt that the network of the gill is truly vascular. Speaking, therefore, of the branchial sac as a perforated membrane, as is frequently done, gives an erroneous idea of its apparently true nature.

The longitudinal bars which have been so frequently alluded to, and which lie in a plane a little above the inner surface of the respiratory sac, are non-essential parts of the organ, their function apparently being, as previously stated, to protect the surface of the gill, and, by the aid of their cilia, to sweep the alimentary matters towards the oral lamina. They are not always developed; they do not exist in *Clavelina*; neither are they apparently present in *Perophora*; and they seem to be absent in several of the compound Ascidians; in *Doliolum* they have likewise disappeared.

It is stated above, that *Clavelina* is nearly related to *Salpa*; but *Pyrosoma* and *Doliolum* come much nearer to it in their general structure, as well as in the details of their organisation. Unfortunately I have never seen either of these two interesting forms; but, judging from the able descriptions of them by Prof. Huxley in the 'Philosophical Transactions,' they both present examples of imperfectly-developed gills. In *Pyrosoma* the secondary vessels are entirely absent, and the primary vessels of the two lateral laminæ of the branchial sac do not reach the endostyle, their development having been arrested before they extended so far across the respiratory cavity; their distal extremities, however, will undoubtedly open into the system of pallial sinuses; in no other way can the flow of the blood through the gill be explained: the circulation is therefore to this extent embryonic. "The longitudinal bars" of Huxley are the homologues of what have been so designated throughout this communication, and are

therefore not to be confounded with the true vascular portion of the gill. To turn *Pyrosoma* into a *Salpa*, little more seems necessary than to arrest entirely the growth of the primary branchial vessels, and to give to each individual a separate test.

An arrest of development of these vessels is carried to a much greater extent in *Doliolum*. In this form the secondary vessels have not only disappeared, but the longitudinal bars are also absent, and the primary vessels themselves only very imperfectly developed. The two bands named by Huxley respectively the "epipharyngeal" and "hypopharyngeal" in this curious form, undoubtedly indicate the line of the great ventral channel and oral lamina, bent up in accordance with the peculiar development of the creature. In the *Ascidiæ* that have the branchial sac prolonged behind the mouth, the ventral channel extends likewise behind the mouth, as well as in front of it; and if we suppose the endostyle to be shortened in these species, and the posterior portion of the sac to be consequently drawn backward and upward, the corresponding extremity of the ventral channel would pass up the dorsal side of the pallial or branchial chamber; and thus this axis of the gill would at once take up the position it occupies in *Doliolum*: that is, part would be above or in front, and part below or behind the mouth; part would form a "hypopharyngeal" band, and part an "epipharyngeal" band.

Now the primary vessels or "tubular bars" originate in the sides of these bands, and are, as already stated, very imperfectly developed, extending, as they do, only for a short distance, and then terminating by opening through the lining membrane of the respiratory cavity into the pallial sinuses, just as we have supposed the similar vessels to do in *Pyrosoma*. The vessels or "bars," however, of the middle portion of the gill, according to Prof. Huxley, do not so terminate, but end in free loops. The branchial sac is, indeed, in such a rudimentary condition that one step more in its degradation and it would entirely disappear, and *Doliolum* would be scarcely distinguishable from *Salpa*.

In *Appendicularia* the gill is wholly absent; but the oral lamina is represented by the "ciliated band," which adheres to the ventral surface of the respiratory cavity; and it is interesting to find that the anterior extremity of this band divides into two branches, which, passing towards the dorsal region, encircle the cavity a little below the ganglion, just as the anterior ciliated band does in *Salpa*, and as the anterior band or collar does in *Ascidia*.

In this interesting form, in which the embryonic characters have become permanent, we see the oral lamina still adhering to the wall of the respiratory cavity, as well as the endostyle and anterior collar or ciliated band. All these parts, then, appear to be equally developments of the lining membrane; and the gill, which in the higher forms has been described to originate in the oral band, or rather in the great ventral channel, which always accompanies it, must likewise be considered a production of this same membrane, with which, too, we have seen that it is connected throughout its development.

The Relationship of the Tunicata with the Polyzoa and Lamellibranchiata.

It is not my intention, on the present occasion, to enter at any length on the relation that subsists between the Tunicata and the Polyzoa on the one hand, and the Tunicata and the Lamellibranchiata on the other. Nevertheless it seems desirable to say a few words on this important branch of the subject before concluding, with the view merely of indicating what appears to be the result, in this respect, of my recent investigations.

That the Polyzoa are very closely allied to the Tunicata is now generally admitted; opinion, however, is divided respecting the homology of the tentacular crown—some naturalists maintaining that it is represented by the branchial sac, while others believe that it is homologous with the tentacles of the respiratory tube, and that the branchial sac is really the dilated pharynx of the polyzoon. These two views have been ably advocated respectively by Prof. Allman and Prof. Huxley.

In my paper on the "Freshwater Bryozoa," before cited, the opinion that the branchial sac is homologous with the tentacular crown was maintained; but my belief in this view has been of late much shaken, and even Prof. Allman's ingenious explanation of his theory seems to me no longer satisfactory. The peculiar idea entertained by this able physiologist is, that the lophophore of a Hippocrepian Polyzoon is the homologue of the ventral branchial channel of the Ascidian, and that the tentacles of the former correspond to the transverse or primary vessels of the branchial sac. But the lophophore is an appendage of the mouth, and is developed from the margin of the oral orifice, and therefore can scarcely be considered to be the true representative of the branchial channel, which does

not seem to be so related, but appears rather to be developed in connexion with the lining membrane coating the pallial cavity, and has all the appearance of a true vessel in direct communication with the heart. And there are other difficulties in the details of this view, to which it is unnecessary, at this moment, to make further allusion.

The view so forcibly advocated by Prof. Huxley seems to rest more upon a wide and philosophical generalization of Molluscan organization than on anatomical and embryological data, and is therefore difficult to discuss from a standpoint of the details of such matters. It must, however, be stated that the anatomical facts, so far as I have been able to examine them, do not seem to contradict this hypothetical view; indeed, in many respects, they appear rather to support it. The anatomical data, nevertheless, will, I think, bear another interpretation, which, perhaps, it will be well to consider, merely premising that I have no wish to support it further than as a suggestion which has a few corroborative facts in its favour: more information is still required before this matter can be determined satisfactorily. The interpretation alluded to is, that the branchial sac is a new and distinct development, as the endostyle is, and as are the oral lamina, the branchial tubercle, and the tentacular filaments of the inhalant tube,—and that all these organs have equally their origin in the lining membrane or inner tunic of Huxley, and have no homological representatives in the Polyzoa.

And, further, this interpretation of the facts leads to a belief that the branchial sac is the rudiment of the Lamellibranchiate gill, the structure of the two organs being essentially the same. The principal blood-channels in the gills of the Lamellibranch are simple transverse vessels; and the most persistent and essential parts in the structure of the branchial sac of the Tunicates are the transverse or primary vessels. Thus, fundamentally, these organs are similar. And when the branchial sac is furnished with longitudinal folds, as generally is the case in the Cynthiadæ, the primary vessels assume relatively the same position as their supposed homologues do in the gill-plate. The folds, too, as the nature of the structure implies, are formed of two laminæ united at their distal margins, and have the space between them divided by septa into transverse pouches, which only want to be elongated by the further development of the fold to make them correspond in every respect to the interbranchial water-tubes of the gill-plate of the Lamellibranch. And already the pouches subserve the function of water-tubes.

Now we have seen that the branchial sac is composed of two lateral laminæ, originating in the great ventral channel, and extending to the endostyle; and in *Pyrosoma* and *Doliolum* we observe that these laminæ are curtailed in their development before they reach so far; in the latter, in fact, they are exceedingly limited. There is, therefore, no difficulty in supposing that the branchial sac might be reduced to merely four such folds as above alluded to, two being on each side of the mouth and oral lamina. Were such the fact, there would be four rows of orifices, corresponding to the pouches in the folds on the outside of the gill, opening into the cloaca, exactly like the four rows of openings of the interbranchial water-tubes communicating with the anal chamber in the Lamellibranchs. Thus, in all external characters, we should have here a very complete representation of the four gill-plates of that group. Each pair of the gill-plates, however, in the Lamellibranchiata has its own proper efferent blood-vessel leading directly to the heart; while our supposed transformed organ has only one such trunk vessel. It would therefore seem probable that the branchial sac can represent but a single gill of the Lamellibranch, and that one fold on each side of the ventral lamina (or great ventral channel) may be assumed to be the homologue of the left gill of the higher mollusk.

The branchial sac itself is not a perfectly symmetrical organ; at least the oral lamina does not exactly divide it into two equal lateral halves; for it invariably passes to the right of the oral aperture in all dextral species, and it never, so far as my observations extend, abuts directly upon it. On the other hand, the heart in the simple Ascidians usually occupies a central position, being placed in the middle line of the digestive organs; and the great vascular trunks, as they leave its anterior or ventral extremity, exhibit a symmetrical bilateral development, a trunk going to each side of the visceral mass, and there ramifying over these organs. That, however, on the left side sends a large branch along by the side of the intestine to the great ventral channel of the gill; while the corresponding branch of the right side dies out before reaching the opposite margin of the visceral mass. Here, then, ceases the bilateral symmetry of the vascular organs; were it carried a little further, there would exist two ventral branchial channels; and thus a right pair of gill-plates might be developed, one fold being on each side of the channel; and in this way the respiratory organ would be exactly similar in all essential characters to that of a Lamellibranch. And if the roots of the two lateral trunks

that proceed from the heart were dilated into auricles, the rudiments of the Lamellibranchiate heart would also be established. This idea of an arrest of a bilateral growth is somewhat strengthened by Krohn's description, already quoted, of the development of *Ascidia mamillata*, in which the young at first has two distinct lateral atrial spaces and two lateral excurrent orifices; the spaces ultimately coalesce, as do also the orifices, the tendency to bilateral development terminating at a very early period.

If this view of the homologies of these organs be correct, then the cloacal, or that which has been uniformly designated throughout this communication the ventral surface, will correspond to the dorsal region of the Lamellibranch; and consequently the opposite margin will be the ventral aspect, and the so-called right and left sides will have to interchange appellations. Thus the excurrent tube will become dorsal, and the incurrent ventral, as they are in the Lamellibranchiata, and, without any great disturbance of the parts, all the viscera will assume their proper positions.

Before the probability of this determination of the homological relations can be admitted, it is necessary to ascertain the true nature of the ganglion, which, as we have seen, is placed between the respiratory tubes. In the Polyzoa the ganglion is placed on the rectal aspect of the œsophagus, immediately below the mouth, and gives its nerves to the tentacles and to the œsophagus in the direction of the mouth, but none to the "endocyst" (mantle) or to any other organ. Therefore it can scarcely be homologous with the ganglion in the Tunicata, which distributes all its nerves to the walls of the respiratory tubes (which are mere prolongations of the mantle) and to the mantle itself. In the Lamellibranchs, however, there is a ganglion (or a pair of ganglions), namely the branchial, the most constant in these animals, situated upon the posterior adductor muscle, which, besides supplying the gills, gives nerves to the dorsal portions of the mantle and to the respiratory tubes, parts which are the undoubted homologues of those which receive the nerves from the ganglion in the Tunicata. It therefore seems impossible to avoid the conclusion that the ganglion in the latter is the true representative of the branchial ganglion in the Lamellibranchiata: ganglia supplying homologous parts must likewise be homologous.

This determination of the nature of the ganglion agrees well with its position, which in relation to the respiratory tubes is almost precisely similar to that of the branchial

ganglion. And we thus find in the nervous element a corroboration of the above suggestion as to the homological relation of the branchial sac.

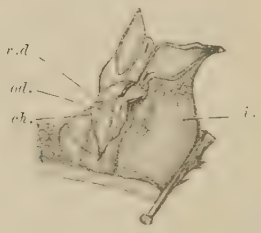


Fig. 12.—*Ascidia mentula*. *i.* Intestine. *v.d.* Vas deferens. *od.* Oviduct. *ch.* Blood-channel laid open. This channel lies immediately below the reproductive channels and between them and the mantle.

CLASS TUNICATA.

Animal acephalous, soft, or coriaceous, simple or compound, without shelly covering or hard parts, having two envelopes or tunics and two apertures, an inhalent and an exhalent. *Outer tunic* or *test* varying in form in the different families, from a simple sac in the solitary or social to a common gelatinous envelope in the compound species. *Inner tunic* or *mantle* always soft and sac-shaped. *Branchiæ* forming a large internal cavity more or less reticulated. Circulation alternately reversed at short intervals in opposite directions. Hermaphrodite.

Order 1. *SACCOBRANCHIATA.*

Animal usually sessile and generally attached, more or less sac-shaped, simple or compound. *Branchiæ* forming an internal reticulated sac. Undergoing a metamorphosis, the young in its first or larval state being tadpole-shaped and swimming freely through the water by means of a long vibratile tail.

Tribe 1. SOLITARIÆ.

(*Simple and Social Ascidians.*)

Individuals single or united into groups at the base, sac-shaped or occasionally elongated, with two tunics, the outer (test) coriaceous or membranous, the inner (mantle) soft and muscular, enclosing the viscera. Two tubular or papillose apertures (the branchial or inhalent and the anal or exhalent), usually not far apart, never at opposite ends. *Branchial sac* generally occupying a large part of the interior of the body. *Branchial orifice* with a circle of tentacular, tubercular filaments.

Family 1. Ascidiadæ.

Animal simple, fixed, sac-shaped, coriaceous or gelatinous. *Test* adhering to the mantle at the two orifices only, except at the point where the blood-vessels pass through. *Branchial aperture* eight-lobed, *anal aperture* six-lobed, with ocelli between each lobe. *Tentacular filaments* simple, linear. *Branchial sac* without folds.

Genus 1. **ASCIDIA** Linnæus, 1767.

Ascidia (pars) Linnæus Syst. Nat. ed. 12, I [2, 1767], p. 1087; Müller Zool. Dan. Prod. (1776), p. 225, and Zool. Danica (*passim*) [1788–1816]; Fabricius Fauna Grœnl. (1780), p. 330; [Bruguière Hist. Nat. Vers, I (1789), in Encycl. Méth. p. 141]; Bosc Hist. Nat. Vers, I (1802), p. 98; Lamarck Hist. Nat. Anim. sans. Vert., ed. 1, III (1816), p. 115, and ed. 2, III [1840], p. 524; Cuvier Règne Animal, II (1817), p. 497; Blainville Man. Malac. et Conch. [1825], p. 583; [Stark Elem. Nat. Hist. II (1828), p. 117;] Forbes and Hanley Hist. Brit. Moll. I [1848], p. 30; Alder and Hancock Cat. Moll. Northumb. and Durh. in Trans. Tyneside N.F. Club, I [1848], p. 199; Gosse Man. Marine Zool. II [1856], p. 35; [Thompson Nat. Hist. Ireland, IV (1856), p. 359].

Phallusia Savigny Mém. Anim. sans. Vert., pt. 2 (1816), p. 161; Milne-Edwards [Obs. Ascid. Comp. in Mém. Acad. Sci. XVIII (1841)].

Pirena and *Phallusia* (pars) Fleming Brit. Anim. (1828), p. 468.

Ascidium (of Baster) Woodward Man. Moll. [1856], p. 337; H. and A. Adams Gen. Recent Moll. II [1858], p. 589.

Animal ovate, coriaceous, semi-transparent, partially contractile, sessile, and usually attached by the right side. *Branchial aperture* 8-lobed, *anal aperture* 6-lobed, with the ocelli more or less conspicuous. *Tentacular filaments* linear. *Branchial sac* large, generally extending to the bottom of the mantle; the meshes rectilinear, with papillæ at the intersections. *Stomach and*

intestine lateral. *Reproductive organs*—ovaries usually confined to the left side.

The *Ascidium* of Baster, there can scarcely be any doubt, is a *Cynthia*. But the Linnæan genus *Ascidia* undoubtedly comprised both true *Ascidiæ* and *Cynthiæ*. There can, therefore, be no doubt as to the propriety of giving precedence to the name *Ascidia* over that of *Phallusia* of Savigny, which has been pretty extensively adopted by naturalists, though it was not used until many years after the date of the twelfth edition of the 'Systema Naturæ'; and indeed were there any doubt respecting the genera included in that work the priority of *Ascidia* is sufficiently established by the employment of that name by Müller and Fabricius in their respective works quoted in the above synonymy.

Much of the internal structure of the *Ascidiæ* has been worked out by Cuvier, Savigny, and others, though not with that minuteness which science now requires. Professor Huxley has also done much and earnestly in this field of inquiry, but the detailed results of the labours of this able anatomist have not been given to the world. We have therefore thought it necessary, in the following account of the anatomy of the Ascidiæ, to go pretty fully into the subject, and more especially as the structure of these, the more highly organised, Tunicates, will not infrequently be used throughout this work as a standard of comparison by which to estimate the structural differences of the various groups.

The test of *Ascidia* is firm, thick, and elastic, and more or less transparent; it is usually smooth, though not infrequently coarse, aculeated, or scabrous, and occasionally covered with extraneous matter. It is sometimes delicately coloured, but is more frequently of a watery tint. It is attached to the mantle only at the extremities of the respiratory tubes, and at the point where it receives blood-vessels. The mantle in some species is ornamented with vivid colours, and is well supplied with muscular fibres which run in various directions.

The mouth opens at the bottom of the branchial sac towards the ventral margin. In some of the species, however, as in *A. mentula*, for example, the branchial sac extends backwards some way behind the oral orifice. The œsophagus is short and constricted; it opens into the anterior or ventral extremity of a well-marked stomach, which is usually a wide rounded sac laterally compressed, lying diagonally across the pallial chamber between the right pallial wall, to which it is adherent, and the branchial sac. The intestine is a wide even tube. It passes from the opposite or dorsal extremity of the stomach, and ascends for some distance, when it crosses over to the other or ventral side in a more or less undulatory course, thus forming one or two loops, and then ascends again to reach the cloaca a little in advance of where the œsophagus joins the branchial sac. Here it terminates in a wide anal opening.

The whole alimentary tube is lined with a stout mucous membrane which is frequently plaited or wrinkled. This membrane forms in the intestine a strongly defined groove which is extended into the stomach.

In all the *Ascidiæ* the alimentary tube is coated externally with a pretty thick layer of a gland-like substance composed of comparatively large, globular vesicles with thin reticulated walls, each having in its wall a large, opaque, simple or compound nucleus (fig. 2, p. 24). These vesicles have no communication with each other, they are not connected with any duct, nor do they open in any way into the alimentary tube. This gland-like substance cannot subserve the function of a liver, though by some naturalists it has been suggested that it does so.

The true hepatic organ lies beneath this vesicular mass, and forms a thin coating on the surface of the intestine (fig. 3, p. 25). It is composed of delicate tubes dividing dichotomously, but frequently without much regularity. At the points where the branches

are given off, the tubes are usually enlarged, and the twigs terminate in rounded extremities which are more or less inflated.

In *A. mentula* the dichotomous division of the tubes is very obvious, and the enlargements or ampullæ at the junctions of the branches are greater than usual and assume a triangular form. Oval enlargements also frequently occur among the branches, which latter, uniting, go to form two long slender ducts which pass backward within the loop of the intestine, buried amidst the vesicular substance already described, and at length open through the left wall of the stomach about midway between the cardia and pylorus, towards the anterior margin. These two ducts come from the middle portion of the intestine; another duct, passing from the lower portion, unites with one of those first mentioned just before it sinks into the wall of the stomach.

In *A. sordida* and *A. scabra* the arrangement of the parts of the hepatic organ is similar to that in the above species.

The reproductive organs are well developed in the *Ascidiæ*, and in all of them the sexes are combined, as is usually the case in the whole class. The male and female elements are, however, always secreted by distinct organs, which are provided with their respective ducts.

In *A. sordida* the ovary is composed of numerous tubular branches which ramify in a radiating manner over the left side of the looped portion of the intestine. The oviduct passes through the loop, and, following the curvature of the intestine, opens by the side of the anus into the cloaca. The *vas deferens* terminates near the same point, and is adherent to the oviduct throughout its course. In the vicinity of the ovary it receives several much-attenuated branches from either side of the intestine; these divide dichotomously, the ultimate twigs terminating in elongated and irregularly lobulated vesicles, which are spread over the intestinal

lobe, and which also exhibit a tendency to dichotomous division; these are the male secreting vesicles.

In *A. scabra*, *A. affinis*, *A. mentula*, *A. venosa*, etc., the same arrangement of the reproductive organs obtains, but the ovary in *A. mentula* is lobulated, and, lying within the loop of the intestine, is seen at both sides of the alimentary tube, and consequently has the appearance of being double. In *A. venosa* the male vesicles are exceedingly minute and very numerous.

The heart in *Ascidia* is tubular and is attached to the lower or posterior border of the stomach, one end extending some way up the dorsal region towards the intestinal tube; this is the dorsal extremity; the other, the ventral extremity, points in the direction of the œsophagus. It lies between the mantle and the lining membrane within a distinct chamber or pericardium, along one side of which it is attached from end to end (Plate III, fig. 4).

A large trunk vessel passes from the dorsal extremity of the heart and immediately divides into three branches, one of which advances along the dorsal region at the back of the endostyle; another passes in the opposite direction down the dorsal margin to the bottom of the branchial sac. These two form the dorsal branchial channel, and are equivalent to the ventral or thoracic sinus of Milne-Edwards; and they both communicate with the dorsal extremities of the transverse channels or primary vessels of the branchial sac. The third branch turns off at right angles to this great dorsal channel close to the point where it is united to the heart, and, in company with another vessel to be shortly described, penetrates the mantle, and goes to ramify in the test.

From the other extremity of the heart there are two large trunk vessels given off, one to each side of the stomach. These ramify over the digestive organs and supply the pallial plexus. The trunk branch of the left side divides into two large stems, one of which inclines towards the intestine, the other towards the

œsophagus; the former, penetrating the mantle in the dorsal region, goes associated with the third branch from the dorsal extremity of the heart to ramify in the test. Thus originate the double vessels which carry the nourishing fluid to and from the outer tunic. The stem that goes towards the œsophagus turns aside to join the great ventral branchial channel, the dorsal sinus of Milne-Edwards, which communicates with the ventral extremity of the transverse branchial channels (Plate III, figs. 2 and 3). These latter channels, or primary branchial channels, communicate also with the visceral and pallial plexuses through the agency of the branchial suspenders. Thus every portion of the organism is brought under the influence of the heart.

When the heart pulsates in the direction of the dorsal extremity the blood is at once thrust into the test and branchial organ; a portion of it will then find its way by the suspenders into the pallial plexuses of both sides and into the visceral plexus, and thus to the ventral end of the heart, before reaching which point, however, it will mingle with that from the great ventral branchial sinus and that returned from the test. Thus the blood which reaches the heart is only partially aerated, as neither that which circulates in the test nor that which comes directly from the visceral and pallial plexuses can to any extent be aerated. When the action of the heart is in the opposite or ventral direction, the reverse of this will take place, but then the only unaerated portion of the blood-return is that which has supplied the test.

The pulsations of the heart are not of equal number in each oscillation; there is usually a little variation in this respect. In a young individual of *A. sordida* in which the pulsations were counted there were 138 in one direction and 120 in the other.

The minute structure of the branchial sac varies a little in the different species of this genus. The simplest form of the structure is found in *A. venosa*. In this species the transverse or primary vessels or

channels are placed at regular intervals and scarcely vary at all in size; and between and opening into them at right angles are numerous small longitudinal secondary vessels divided by elongated spaces or stomata, so that the whole forms a reticulation of vessels, in which the transverse channels are large and distant, the longitudinal small and numerous, and divided only by narrow open spaces (Plate X).

This simple structure of the aerating organ is not usual in the *Ascidiæ*, though it is fundamentally the same in all. In *A. mentula*, *A. sordida*, *A. scabra*, *A. affinis*, and their allies, the simple reticulated branchial web of *A. renosa* has, as it were, become minutely folded or plaited longitudinally, so as to give to the surface the appearance of corduroy, but the flutes or grooves between the ridges or plaits are interrupted wherever the transverse vessels cross them, turning them into series of minute recesses or pouches.

The longitudinal bars which project from the true aerating surface of the branchial sac extend the whole length of the organ; they are usually stout and rather rigid, and are attached only at the points where they cross the primary transverse vessels, and at this point, too, they have projecting from their upper surface elongated papillæ which usually bear ciliated discs, and have a wide membrane stretched from the back for a considerable way along the transverse vessels. In *A. mentula* and allied species there are small intermediate papillæ between those at the points of intersection. In *A. sordida*, *A. scabra*, and *A. affinis* there are no intermediate papillæ on the bars, but in all of them the papillæ at the points of attachment are in connection with a wide membranous expansion, and distinct ciliated discs are arranged in pairs on the transverse vessels between the longitudinal bars. In some species there is a ciliated disc on the bars between the papillæ. In *A. renosa* the bars are more delicate than usual, and the membrane in connection with the papillæ is inconspicuous.

The oral lamina is well developed in all the *Ascidiæ*. It is usually a wide plane membrane extending along the ventral margin of the branchial sac from one extremity to the other, passing on the right of the oral orifice in those species in which the sac is prolonged backwards; in those with the sac not so prolonged it terminates at the right side of the mouth. In many of the species the oral lamina is transversely ribbed; the ribs are strongly developed in *A. mentula*, [*A. Alderi*, *A. aculeata*, etc.,] and in these species they pass beyond the margin as fine points, giving to the lamina a pectinated appearance; the function of this organ is to convey the food to the mouth (Plate XIX).

The endostyle extends the whole length of the branchial sac, and is in connection with two membranous folds which form a longitudinal groove and within which it seems to be embedded. It is composed of two flattened rods of a rigid, opaque, yellow substance. The folds are in connection with the anterior cord or collar, a narrow cord-like fold of the lining membrane which encircles the entrance to the branchial sac, and which is likewise in connection with the oral lamina. Below, the folds of the endostyle are also connected to the oral lamina by a similar cord-like fold.

The circle of tentacular filaments within the base of the incurrent tube is always situated a little above the entrance to the branchial sac (Plate III, fig. 1). The filaments vary in size and number in the different species in the whole of the genus, but are always linear and pointed or slightly conical.

The branchial tubercle, that curious and enigmatical organ situated immediately in front of the upper extremity of the oral lamina, at the entrance of the branchial sac, is composed of two folds of the lining membrane pressed close together, and convoluted more or less in the various species so that it usually assumes the form of a rounded or oval, depressed, compact, tubercular swelling (Plate XX).

The single ganglion of the nervous system of *Ascidia* is, as usual, placed between the respiratory tubes. It lies in a blood-sinus situated between the inner tunic and lining membrane. It is fusiform, varying little in character, and is partially folded in a much folliculated gland-like substance, as determined in *A. mentula* (figs. 10 and 11, p. 50) and in some other species. Three or four nerves are given off from each extremity, all of which go to the respiratory tubes and to the adjacent portions of the inner tunic or mantle. A branch from one of the principal nerves has been traced to the branchial tubercle.

1. **Ascidia mamillata** Cuvier.*

(Pl. I, and fig. 13 in text.)

Ascidia mamillata Cuvier [Mém. Ascidies in Mém. du Mus. II (1815), p. 30, pl. iii, and Mém. Asc. p. 22, pl. iii, in] Mém. des Moll. (1817); Lamarck Hist. Nat. Anim. sans. Vert. ed. 1, III (1816), p. 125; ed. 2, III [1840], p. 532.
Phallusia mamillata Savigny Mém. Anim. sans. Vert. pt. 2 (1816), p. 168.
Ascidia arachnoidea Forbes in Brit. Moll. I [1848], p. 32.

Body oblong-ovate, opaline, white or yellowish, mamillated with unequal rounded eminences. *Apertures*, branchial terminal, anal about one-third down, generally terminating on the left side; ocelli inconspicuous. *Test* thick, firm, and cartilaginous, smooth, and of a porcelain-like lustre, more or less marked with delicate branched or net-like lines. *Mantle* dark blue. *Tentacular filaments* few and rather small. *Branchial sac* with rather broad papillæ. [*Oral*

* The habitat and first British record of each species have been added when ascertainable; if from the authors' MS., without indication of interpolation; if from other sources, inserted within brackets. As the localities are not in any definite order in the MS., they have been rearranged throughout, referred (with the exception of districts and well-known islands) to their counties, and grouped under the different countries of the British Isles. No addition has been made, either to the synonymy or localities, from information published more recently than 1870.

lamina narrow, strongly pectinated or transversely ribbed. *Branchial tubercle* inconspicuous.]

Length from three to four or five inches.

Hab.—Adhering to loose stones, etc.

England.—Not uncommon on the south coast; rare or entirely absent in the north. Lulworth Cove (*Jeffreys*) and Weymouth (*Gosse*), Dorset. Salcombe Bay (*Hincks*), Tor Bay (*Alder*), and Plymouth (*Stewart*), Devon. [Falmouth, Cornwall (*Cocks*, 1849).] Isle of Man, rare (*Alder*).

Scotland.—Lamlash Bay, Arran, rare (*Alder*).

First record.—Forbes, 1848, as *A. arachnoidea.*

This species (Pl. I) adheres diagonally by the base, from which it often throws out ramifications of the test to a considerable distance, running among loose stones and binding them together into a compact mass. On account of the bend of the mantle and branchial sac upwards, the anal aperture is displaced from its usual ventral position, and appears generally on the left side, sometimes even assuming a sub-dorsal aspect.

The bending of the body upwards is a very striking feature in the species, and does not merely alter the situation of the excurrent tube as stated above, but throws many of the organs out of their regular position. The bend is to the right side, inclining towards the ventral margin, and the lower extremity of the mantle is brought nearly as far forward as the anterior border of the intestinal loops. The branchial sac, which extends to the lower end of the body, is also bent upwards, and consequently the endostyle forms a very wide loop; the heart is likewise bent in the same direction, and the upper portion of the endostyle is drawn somewhat towards the ventral margin. In fact, while the dorsal margin is in a manner much elongated, the ventral margin is greatly shortened, so that the oral band can be little more than one third the length of the endostyle. The band itself is narrow and strongly pectinated or ribbed transversely, and is in front split into two lateral mem-

branes much farther downwards than usual. The collar of tentacular filaments at the base of the inhalant tube is very near to the anterior margin of the branchial sac; and there are fifteen or sixteen rather short filaments, with two or three minute ones between them. But what is most peculiar in this species is the deficiency of the branchial tubercle or any trace of it; we have examined three specimens and in not one of them could we find this enigmatical organ so constant in the Tunicata.

The branchial membrane (fig. 13) is rather stout and is minutely plicated longitudinally; the primary

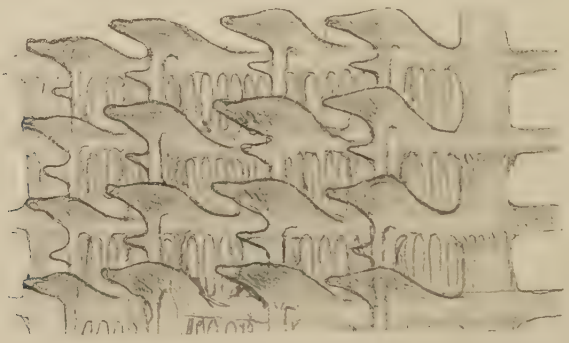


Fig. 13.—Part of the branchial sac of *Ascidia mamillata*. Highly magnified.

vessels are numerous and fine, with a few larger ones interspersed. The longitudinal bars are also numerous and less robust than the primary vessels with which they form square meshes; there is a large conical papilla with the apex rounded, at each intersection, and as the meshes are small the papillæ have a rather crowded appearance, especially as there is a small papilla on the longitudinal bars, between each pair of large papillæ, and the membrane in connection with the latter is short. The meshes or stomata of the secondary vessels are of the usual rectilinear form, but are less elongated than in many species.

The reproductive organs are confined to the right side of the body. The testicular cæca are spread over

and are partially buried amidst the cellular matter of the intestine, but are mostly accumulated towards the dorsal border. The minute twigs of the duct are greatly enlarged in places, are irregularly tuberous or nodose, and give off short cæcal processes. There is but one ovary, which lies concealed in the cellular matter at the upper extremity of the intestinal loop; it is an elongated sac with the duct at first small, but on passing through the loop of the intestine it is much enlarged when it reaches the other side of the body.

There can be little doubt that the *Ascidia arachnoidea* of Forbes is identical with the *A. mamillata* of Cuvier. The rich supply of blood-vessels ramifying through the test in this species, and rising towards the surface in the smaller ramuli, give it that delicately reticulated appearance which suggested to Professor Forbes the name of *arachnoidea*. That distinguished naturalist dredged it in the Ægean, whence it appears to range to the south and west of England, disappearing farther north.

2. **Ascidia mentula** Müller.

(Pl. II; III; XVII, fig. 1; Pl. XX, fig. 1; and figs. 5, 6, 10, 11, 12, and 14, in text.)

Ascidia mentula Müller Zool. Dan. Prod. [1776], p. 225, no. 2724, and Zool. Danica, I [1788], p. 6, pl. viii, f. 1–4; Fabricius Fauna Grœnl. [1780], p. 331; [Montagu Test. Brit. II (1803), p. 532;] Lamarck Anim. sans. Vert. ed. 1, III [(1816), p. 125]; ed. 2, III [1840], p. 532; [Stewart Elem. Nat. Hist. I (1817), p. 391; Bruguière] Vers, I [1789], p. 145, pl. lxii, f. 2–4, in Encycl. Méth.; [Stark Elem. Nat. Hist. II (1828), p. 117;] Dalyell Rare Anim. Scotland, II [1848], p. 146, pl. xxxvi, f. 6, and pl. xlvi; Forbes and Hanley Brit. Moll. I [1848], p. 32, pl. C, f. 1; [Carus Zool. Scilly Isles in Proc. Ashmol. Soc. II (1851), p. 266; Landsborough Excurs. Arran (1852), p. 49; Thompson Nat. Hist. Ireland, IV (1856), p. 359; Norman in Zoologist, XV (1857), p. 5707: Merrifield Nat. Hist. Brighton (1860), p. 80; McIntosh in Proc. R. Soc. Edinb. V (1866), p. 605; Alder in Rep. Brit. Assoc. 1866 (1867), p. 207; Norman in Rep. Brit. Assoc. 1868 (1869), p. 302].

Ascidia monarchus Cuvier Mém. Ascidies in Mém du Mus. II (1815), p. 32.
Phallusia monarchus Savigny Mém. Anim. sans. Vert. pt. 2 [1816], p. 167, pl. x, f. 2.
[*Phallusia mentula* Fleming Brit. Anim. I (1828), p. 468.
Ascidia mentula et communis (Forbes MS.) Thompson in Ann. Nat. Hist. (1) XIII (1844), p. 434.
Ascidia communis Forbes (MS.) in Rep. Brit. Assoc. 1850 (1851), p. 242.]
Ascidium monarchus Woodward Man. Moll. [1856], p. 337, f. 224.
[*Ascidium mentula* Adams Gen. Rec. Moll. (1858), pl. cxxxiii, f. 1.]

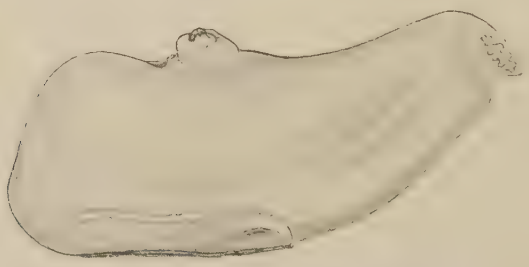


Fig. 14.—*Ascidia mentula.* One-half natural size.

Body oblong or irregularly ovate, and much produced towards the upper end; coarse, horn-coloured, but varying from greenish white to very dark brown, usually adhering more or less by one side. *Apertures* distant, sessile, the branchial one terminal, the anal on a bulging of the side, about two-thirds down; ocelli yellow with a central red spot. *Test* thick, tough, and cartilaginous, semitransparent; occasionally roughly furrowed, but not tuberculated; often with irregular swellings produced by imbedded mussels. *Mantle* red, especially towards the apertures; greenish, or inclined to brown. *Tentacular filaments* rather numerous, of equal length; mostly stout. *Branchial sac* with moderate-sized papillæ at the intersections of the meshes, and intermediate smaller ones on the longitudinal bands or bars. *Oral lamina* transversely ribbed and strongly pectinated.

Length usually from four to six inches (occasionally much longer).

Hab.—From within tide-marks to deepish water (adhering to rocks, &c.).

England.—[Brighton, Sussex (*Merrifield*, 1860).] Lulworth Cove, Dorset (*Jeffreys*). [Torcross, Devon, dredged, with *Sabella penicillus* adhering to it (*Montagu*, 1803). Falmouth, Cornwall (*Cocks*, 1849). Scilly Isles (*Carus*, 1850).] Isle of Man (*Forbes*).

Wales.—[Tenby (*Woodward*, 1856).]

Scotland.—[Clyde (*Forbes*, 1850). Corrigils, Arran (*Landsborough*, 1852). Lamlash, Arran; and Cumbrae (*Norman*, 1857). Hebrides (*Forbes*, 1850). North Uist (*McIntosh*, 1865).] Not uncommon on the North-west coast (*Forbes*). Orkney Isles (*Allman* and *Forbes*). Shetland Isles (*Forbes* and *Jeffreys*). [Middle Haaf, Shetland (*Norman*, 1868).]

Ireland.—North-west coast (*Thompson*). [Belfast Bay, Antrim; Clew Bay, Mayo; and Roundstone Bay, Galway (*Thompson*, 1844). Bantry Bay, Cork (*Wright*).]

First record.—[Montagu, 1803.]

Ascidia mentula (fig. 14) is attached by a small portion of the side of the body towards the posterior extremity, or diagonally by the base; never, or rarely, by the whole side, as is the case with some of the allied species. The test, which is rather opaque and frequently thick, rough, and coarse, is well supplied with vascular channels, which in specimens preserved in spirits, being yellowish and somewhat opaque, can usually be well observed ramifying in the semitransparent substance of the test. They are much subdivided, and the twigs which approach the inner surface are usually simple, or only occasionally a little enlarged at the extremities; those which are seen at the external surface terminate in irregularly-rounded enlargements.

The mantle is well supplied with interwoven muscular bands, longitudinal, transverse, and diagonal;

the longitudinal ones are not very numerous and are mostly confined to the anterior portion. The tubes are very short, the anal being a little longer than the branchial, the orifice of which is almost sessile.

The branchial sac (Pl. II, and Pl. XVII, fig. 1) is coextensive with the mantle; both extend considerably behind the visceral mass and are reflected a little upwards on the right side as in *A. mamillata*, there being a slight internal ridge across the posterior portion of the test. The branchial sac is prolonged for some distance below the mouth; the walls are minutely, but distinctly plicated; the primary vessels are numerous and vary in size, the larger having several smaller ones between them. The stomata are rather long and wide, with the extremities rounded, sometimes a little pointed. The papillæ are conical, well developed, alternately large and small, and the papillary membrane is unusually ample; the branchial bars are stout, with a widish membrane extending along the inferior margin. The oral lamina (Pl. II) is continued from one end of the branchial sac to the other, diminishing a little in width after passing the mouth; it is wide, strongly ribbed on both sides, and has the margin pectinated in advance of the mouth; behind it the margin is smooth, or nearly so. The belt of tentacular filaments on the left of the mouth reaches to the bottom of the branchial sac, and is strongly developed; the filaments are closely set and numerous, there being sometimes as many as seventy; they are wide at the base and pointed above. The endostyle (Pl. II, Pl. III, fig. 5, and figs. 5 and 6 in text) extends the full length of the gill. The branchial tubercle (Pl. II, and Pl. XX, fig. 1) is usually irregularly rounded, with the extremities turned a little inwards; but the organ is subject to great variation in this species, the extremities sometimes bending in one direction, sometimes in another, and varying in length and extent of convolution. The tentacular filaments at the entrance of the branchial sac are arranged

in a single row on a muscular ridge or collar (Plate III, fig. 1); they vary considerably in size, number upwards of forty, and are usually placed a little apart, and not far above the margin of the branchial sac.

The ovary is situated in the loop of the intestine and is seen at both sides of that organ; it appears as a lobulated, compact mass, and does not extend over the walls of the alimentary tube. The male cæca are conspicuous on the right side of the intestine as white dendritic tufts ramifying over the surface and partially buried in the cellular matter, a thick layer of which is spread over the whole of the digestive organs.

Professor Edward Forbes considers this to be the commonest of our deep-water Ascidians; but it has not yet been met with on the north-east coast of England. It appears to be frequently met with, though not very common, on the south and west coasts. Sars states that it extends along the whole of the Norwegian coast, and also occurs in Greenland and North America. His remark that the tentacular filaments are conspicuous between the ocelli, in both orifices, must refer to the internal folds of the apertures which terminate in points above. The tentacular filaments are confined to one aperture and do not appear outside.

Ascidia mentula is one of the largest and most uncouth-looking of our native Ascidians, often being disfigured by extraneous substances and by swellings caused by *Modiola marmorata* imbedded in the test. Müller says that it is pilose, but this is an error probably occasioned by some small zoophytes covering the surface. Professor Percival Wright informs us that he has met with *Ascidia mentula*, in Bantry Bay, measuring eleven and a half inches long and two and a half broad. A remarkable monstrosity of this species was sent to us from Lulworth Cove by our friend Mr. Jeffreys. It consisted of two perfect Ascidians imbedded in one test, one of them rising perpendicularly above, and the other lying diagonally across, the base.

Externally the test was continuous without depression or indication of any kind that it covered more than one individual, excepting that it had four orifices instead of two; internally there was a ridge dividing it into two cavities, which however were not closed, but communicated freely with each other.

3. **Ascidia robusta** Hancock.

(Pl. XX, figs. 2 and 3; and fig. 15 in text.)

[*Ascidia robusta* Hancock in Ann. Nat. Hist. (4), VI (1870), p. 358.]

Body elongated, irregularly ovate, produced in front, very coarse, with a tinge of red, particularly towards the orifices; adhering by the whole side, but sometimes much distorted and with adherent, root-like prolongations. *Apertures* tubular, much produced, the branchial one terminal, the anal more than half way down, and inclined backwards; ocelli red. *Test* extremely thick, tough, hard, and cartilaginous, usually with root-like prolongations, semi-transparent, very coarse and rough, irregularly furrowed and pitted, and frequently much overgrown with zoophytes. *Mantle* tinged with red, intensified towards the orifices; tubes long, the anal one much produced and turned backwards. *Tentacular filaments* rather slender, not crowded, with small ones between the larger. *Branchial sac* extending a little behind the visceral mass; minutely plicated with well-developed tubercles, alternately large and small. *Oral lamina* ribbed transversely and strongly pectinated near the mouth.

Length from four to five inches.

Hab.—Between the roots of *Laminaria digitata*.

Channel Islands.—[Herm,] Guernsey (*Norman*).

First record.—Hancock, 1870; *coll.* Norman [1865].

This is not only one of the largest, but is perhaps the coarsest, of the British Tunicata. The test (fig. 15) is usually more or less tinged with red, principally

in consequence of the red colouring of the vascular channels. In young specimens, however, it is sometimes of a uniform rose-colour, and in this state it is pretty regular in form, and is attached by the whole side. When full grown the test is remarkably rough, hard, and thick, and frequently much distorted. The larger specimens, obtained at Guernsey by Mr. Norman, were firmly inserted between the roots of *Laminaria digitata*, and so hard were the tests and their prolongations that they were with difficulty cut free with a knife. The blood-channels in the test are more or less of a red colour, mostly rounded and enlarged at the extremity, and rather crowded.

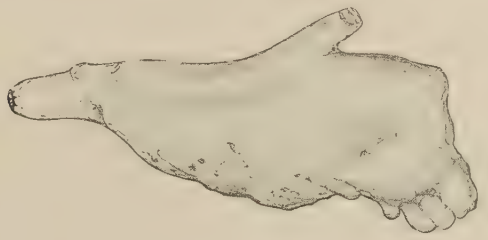


Fig. 15.—*Ascidia robusta*. One half natural size.

The mantle is more or less red in colour, sometimes it is of a full rose-colour heightened towards the orifices. The right or attached side is almost devoid of muscular fibres, but on the other or free side they are numerous, and as it were felted; the tubes are long, particularly the anal, which is turned backwards.

The branchial sac extends only a little way behind the visceral mass; it is minutely plicated. The papillæ are conical, not very wide at the base, and their apices are rather sharp; they are alternately large and small, though nearly of equal length. The endostyle reaches to the bottom of the sac. The oral lamina is not very wide; it is strongly ribbed transversely on both sides, and has the margin slightly pectinated in advance of the mouth where it suddenly narrows; in the neighbourhood of the mouth the pectinations are unusually long;

below the mouth both the ribs and pectinations die out, and the membrane becomes very narrow before it reaches the bottom of the sac. The tentacular points on the left side of the mouth are large and triangular with the apices sharp; sixteen or seventeen above and at the side of the mouth are placed close together; below, they are wide apart, usually few in number and in some instances entirely wanting. The branchial tubercle (Pl. XX, figs. 2 and 3) is oval in the antero-posterior direction, with the extremities not convoluted, but turned directly inwards and downwards. This organ, however, appears to vary, and in two or three instances it was somewhat lozenge-shaped, very large, and composed of numerous irregular convolutions; in others again the loop is small and simple with the extremities turned sometimes to one side, sometimes to the other, and slightly convoluted. The tentacular filaments at the base of the branchial tube are arranged on a delicate muscular collar in a single line rather close to the branchial margin; they vary in number from thirty to forty-five, and are delicate, with smaller ones interspersed.

The ovary is lobulated and placed in the intestinal loop, appearing at the left side. Traces of the male cæca are observed on the right side of the intestine; they are usually, however, obscured by the cellular matter which thickly covers the alimentary tube, particularly the stomach; the cells are smaller than usual.

This species is closely related to *A. mentula* and *A. rubicunda*; the extreme hardness and thickness of the test, however, and the great length of the respiratory tubes, sufficiently distinguish it from both. From the former it is likewise distinguished by its colour, and by several other matters of detail.

4. **Ascidia rubicunda** Hancock.

(Pl. IV, figs. 1 and 2; Pl. XVII, fig. 2; Pl. XX, fig. 4.)

[*Ascidia rubicunda* Hancock in Ann. Nat. Hist (4) VI (1870), p. 357.]

Body much elongated, irregularly oval, depressed, coarse, of an obscure flesh-colour, adhering by the whole side, with imperfect marginal expansions. *Apertures* only a little produced; the branchial one almost sessile, terminal; the anal turned backwards from a bulging at the side, more than half way down; ocelli crimson, small at both orifices. *Test* thick, coarse, wrinkled, cartilaginous, semitransparent, of a flesh-colour, most rosy towards the orifices, occasionally overgrown with zoophytes. *Mantle* of a brilliant rose-colour, much intensified at the tubes, the alimentary tube of a greenish hue, evidently from the nature of the contents. *Tentacular filaments* short and delicate, varying in size. *Branchial sac* minutely plicated, with large conical papillæ, the intermediate ones nearly as large as those at the intersections of the meshes. *Oral lamina* ribbed transversely and finely pectinated from end to end, and of equal breadth throughout.

Length upwards of four and a half inches.

Hab.—[Between tide-marks and at extreme low tides, sometimes on the stems and roots of *Halidrys siliquosa*.]

Scotland.—Hebrides (*Norman*). [Tobermorey, Isle of Mull, 1866 (*Norman*).]

Ireland.—[Portaferry, Strangford Lough, Down (*Norman*). Birterbuy Bay, Connemara, Galway (*More*).]

First record.—Hancock, 1870; *coll.* Norman, 1866.

The test (Pl. IV, fig. 1) is semitransparent, and of a yellowish flesh colour which is usually heightened to a full rosy hue at the respiratory tubes; it is firm, thick, and cartilaginous. The vascular channels are

numerous, with the terminal twigs red in the vicinity of the orifices, and frequently red vessels are scattered over various parts of the test. In some specimens such coloured vessels are numerous everywhere, particularly in young individuals. The twigs at the external surface are comparatively short, and are irregularly enlarged and rounded at the extremities; those ramifying within the inner surface of the test are long and slender, usually swelling gradually towards the ends and occasionally terminating in globular enlargements.

The mantle (Pl. IV, fig. 2) is remarkable for the purity and brilliancy of its colour, the rosy tint becoming almost crimson at the tubes, which though short are distinctly developed, and are of about equal length. The muscular fibres on the left side are fine, numerous, and interwoven, the transverse ones predominating.

The branchial sac (Pl. XVII, fig. 2) extends the whole length of the mantle, and consequently for some distance behind the visceral mass. It is minutely plicated, the plicæ being as numerous as the longitudinal bars. The primary vessels are numerous, rather close together, pretty equal in size, with the exception of a few large ones placed at widish intervals. The secondary vessels are short and not very regular, the stomata varying a little in form, the ends being either pointed or rounded. The longitudinal bars are stout; the papillæ are large and conical, rather crowded; those at the intersection of the meshes are scarcely larger than the intermediate ones; the papillary membrane is not much developed. The oral lamina is rather narrow and of equal width throughout; it is closely ribbed transversely, even to the bottom of the branchial sac, the ribs being strongest on the right side, finely pectinated from end to end, and having the tentacular points on the left of the mouth forming a continuous series to the bottom of the branchial sac; they are closely set, narrow, and pointed. The branchial tubercle (Pl. XX,

fig. 4) varies a little; it is occasionally transversely wide, and sometimes wider in the opposite direction; the extremities are not much or regularly convoluted; they usually bend inwards; but not infrequently the ends turn, the one inwards, the other outwards. The tentacular filaments are short and slender; they vary much in size, some being quite minute, and number from thirty to forty.

The ovary is much lobulated, being most developed at the left side; occasionally it is not perceptible at the right side. The male cæca are found at both sides of the alimentary tube; they are rather conspicuous, usually bifid, cylindrical, with the distal extremities obtuse. The cells coating the alimentary tube are minute and do not form so thick a coat as usual.

Ascidia rubicunda is related to *A. mentula* on the one hand, and to *A. robusta* on the other, but is distinguished from both by many characters. It is always more extensively attached, and is more elongated and depressed than the former, from which it also differs in colour. From *A. robusta* it is likewise distinguished by its great brilliancy of colour as well as by its general form, its shorter tubes, and the less robust character of the test. Many other minor points distinguish it from both.

5. **Ascidia rubrotincta** Hancock.

(Pl. XVII, fig. 3; Pl. XIX, fig. 2; and fig. 16 in text.)

[*Ascidia rubro-tincta* Hancock in Ann. Nat. Hist. (4) VI (1870), p. 356.]

Body pretty regularly oval, smooth, or only very slightly wrinkled, of a pale-reddish flesh-colour, adhering by the middle portion of the side. *Apertures* distant, with the tubes not much produced; the branchial one terminal, the anal more than half way down the side; ocelli red. *Test* rather thin, cartilaginous, pellucid, of a reddish flesh-colour, smooth or slightly

wrinkled longitudinally; tubes short, the anal inclining backwards. *Mantle* rather delicate, yellowish, tinged in parts with a reddish flesh-colour. *Tentacular filaments* numerous, delicate, unequal in size. *Branchial sac* minutely plicated, with rather long, conical papillæ. *Oral lamina* rather narrow, strongly ribbed transversely, with the margin pectinated.

Length about two and a half inches.

Hab.—Between tide-marks.

Channel Islands.—Guernsey (*Norman*).

First record.—Hancock, 1870; *coll.* Norman [1865].

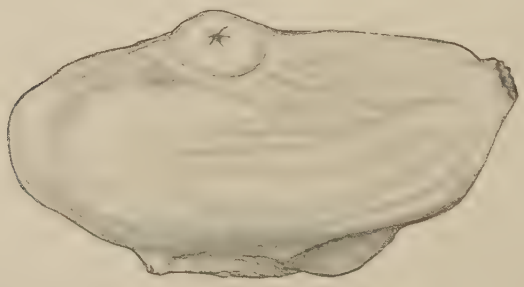


Fig. 16.—*Ascidia rubrotincta.* Natural size.

The test of this species (fig. 16) is well supplied with much-branched blood-channels; the branches are slender with the ends of the ultimate twigs much enlarged, elliptical, or pyriform, appearing at the surface as red points; all the ramifications partake largely of the same colour; the enlarged extremities, however, and the septa dividing the tubes, are most crowded with pigment-cells.

The muscular fibres of the mantle, which are fine, interwoven, and numerous, have a glossy, silky appearance.

The branchial sac (Pl. XXVII, fig. 3) does not extend far behind the visceral mass, and is minutely plicated. The primary vessels are slender, with a few strong ones interspersed at irregular intervals. The secondary

vessels are pretty regular, having the stomata rectilinear, the ends being a little rounded. The papillæ are large, long, and conical, and are situated on the longitudinal bars at the intersections of the meshes, and also on the bars between the intersections; they are of nearly equal size, the intermediate ones being scarcely shorter than the others; the papillary membrane is strongly developed. The longitudinal bars are delicate, with a membranous expansion along the inner margin. The oral lamina (Pl. XIX, fig. 2) is not very wide, but maintains its width for some distance behind the mouth; it never becomes very narrow, but ends rather abruptly at the bottom of the branchial sac; it is strongly ribbed transversely on the right side, and the margin is pectinated throughout; the tentacular points in front, and also at the left side of the mouth, where they number twenty-one, are narrow and united at the base by a membrane; those in continuation of the series below the mouth have only their points free, and of these there are between thirty and forty. The tentacular filaments at the entrance of the branchial sac are delicate and numerous, situated not much in advance of the branchial margin; they are very unequal in size, some being excessively short, others of considerable length. The branchial tubercle is quite minute, and forms a simple loop with the left extremity turned inwards.

The ovary is seen at both sides of the intestinal loop; on the left it has a lobulated appearance, on the right it assumes a branched, tubular form as it becomes united to the extremity of the wide oviduct. The short, wide, cæcal extremities of the male organ are observed on the right side by the margin of the ovary.

A. rubrotincta is a near ally to *A. mentula*, from which, however, it is distinguished not only by its colour, but also by several points of detail. The test is thinner and less coarse than it is in the latter species, and the tubes are better marked, particularly the

branchial; the oral lamina likewise differs in some particulars, as do also the reproductive organs.

We have seen only one individual of this species, and, as the description was drawn up some time after it had been in spirit, it is probable that its colour may have been much brighter than is represented, and indeed may have been somewhat different in kind as well as in degree. It would seem, too, that the blood was probably red; for the blood-channels were in many parts clogged with a reddish matter.

6. **Ascidia crassa** Hancock.

(Pl. XVII, fig. 4; Pl. XIX, fig. 3; Pl. XX, fig. 5; and fig. 17 in text.)

[*Ascidia crassa* Hancock in Ann. Nat. Hist. (4) VI (1870), p. 359.]

Body broadly oval, a little depressed, deeply and irregularly wrinkled, of a pale flesh-colour, adhering by various parts to seaweeds. *Apertures* distant, sessile; branchial sub-terminal; anal about half-way down the side. *Test* very thick, hard, cartilaginous, pellucid, irregularly and strongly wrinkled, of a pale flesh-colour. *Mantle* rose-coloured, deeper towards the margins and over the alimentary canal; the tubes of the apertures short, particularly the branchial one, which is sub-terminal; the anal is a little produced and doubled over towards the left side. *Tentacular filaments* numerous, well-developed, unequal in size. *Branchial sac* minutely plicated, with obtuse papillæ alternately large and small, the stomata very small and elliptical. *Oral lamina* delicately ribbed transversely, and minutely pectinated; by the side of the mouth the pectinations are increased in size and replace the lamina.

Length two inches and a quarter; *breadth* an inch and a half.

Hab.—Between tide-marks, attached to seaweeds.

Channel Islands.—Jersey (*Dodd*), in the collection of the Rev. A. M. Norman.

First record.—Hancock, 1870; *coll.* Dodd [1869].

We have seen three specimens of this well-marked species; they were all from the same locality but had been some time in spirit before they were examined; none of them showed any large area of attachment; on the contrary, they all seemed to have been adherent by various parts of the body to seaweeds, the remains of which, including a piece of the cuticle of *Laminaria digitata*, being impressed into the surface of one of the specimens.

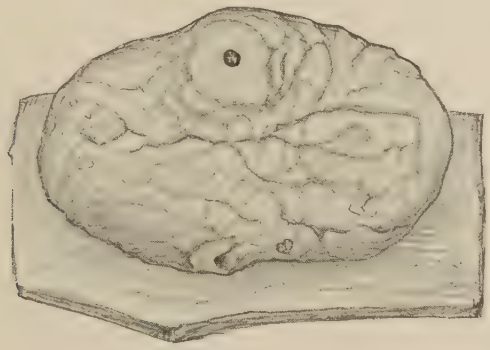


Fig. 17.—*Ascidia crassa.* Natural size.

The test (fig. 17) is unusually thick and hard, and is irregularly and strongly wrinkled; it is pellucid and of a delicate flesh-colour. The blood-channels are numerous and are frequently crimson, especially those appearing at the external surface, which have their extremities considerably enlarged and irregularly rounded or pyriform; those observed at the inner surface have the ultimate twigs slightly swollen and fusiform. The enlarged crimson ones at the exterior are not very plentiful and are mostly confined to the vicinity of the apertures.

The mantle is well supplied with thick interwoven muscular fibres, and varies in colour from a pale rosy hue to crimson, the colour being intensified towards

the dorsal and ventral margins, over the alimentary canal, and at the margin of the orifices. In one specimen a broad belt of brilliant crimson extended along the dorsal margin, commencing in the branchial tube and reaching to the bottom of the mantle. The anal tube in this specimen was also of a deep crimson. The branchial aperture is sub-terminal, being placed a little towards either the left or right side; in one of the specimens it was inclined to the right, in the other two to the left side. The anal tube, which is a little more than half-way down the side, is well produced, but is somewhat constricted and turned over towards the left side.

The branchial sac (Pl. XVII, fig. 4) does not extend backwards beyond the visceral mass; it is minutely plicated; the primary vessels are numerous and regularly disposed, and are placed closer together than usual. The branchial ties are large, with very stout walls. The secondary vessels are short and wide —the stomata being extremely short, wide, and elliptical—many of them not extending the whole space between the primary vessels. The longitudinal bars are stout, with the branchial papillæ rather closely set; the larger ones, at the intersections of the meshes, are rather short and thick with the extremities obtuse; those placed between them are considerably smaller, and are somewhat clavate, their extremities being a little enlarged and rounded. The papillary membrane is ample. The oral lamina (Pl. XIX, fig. 3) is not very wide; the anterior cleft extends further down than usual and is delicately ribbed transversely, the ribs being scarcely visible on the left side; the margin is minutely denticulated. In front of the mouth the lamina dies out, and is replaced for some short distance by a series of delicate tentacular points; below the mouth the lamina is very narrow and indistinctly ribbed and pectinated. The tentacular points on the left side of the mouth are narrow and minute, and arranged in a closely set series; they diminish in size backwards

and terminate before the bottom of the sac is reached; they are largest in the vicinity of the mouth. The tentacular filaments at the base of the branchial tube are about fifty, arranged in a single line on the posterior surface of a muscular ridge or collar; they are rather closely set, moderately long and stout, but vary in size. The branchial tubercle (Pl. XX, fig. 5) is loop-formed, with the extremities turned first inwards, then upwards.

The ovary is placed in the intestinal loop, and appears at the left side as a congeries of lobules. The male cæca were not observed; the *vas deferens*, however, was followed into the loop of the intestine, and the minute branches were traced amidst the cellular matter which coats the alimentary canal, but the cæca, probably from their minute size, escaped detection. Both sides of the visceral mass are densely covered with cellular matter; the cells are minute and do not exhibit the usual dark nucleus when viewed with a doublet.

Ascidia crassa cannot very well be confounded with any other known species; the broadly oval form, the sessile orifices, and hard, thick, cartilaginous test are very characteristic; but the branchial sac presents probably the most distinctive feature. The walls of this organ have a very peculiar appearance, on account of the grooves of the minute plications being formed into series of well-defined minute pouches by the closely-set primary vessels, thus rendering it very difficult to observe the secondary vessels and the unusually diminutive, elliptic stomata. And this difficulty is increased by the excessive development of the external vessels in connexion with the primary system of blood-channels and the branchial ties, forming, as they do, a complete network at the outside of the branchial sac. It is only through the contracted meshes of this network, or through the narrow pouches on the inner surface, that the secondary vessels and the stomata can be seen.

7. **Ascidia mollis** Alder and Hancock.

(Pl. V, figs. 1–6; Pl. XVII, fig. 5; Pl. XIX, fig. 4; and figs. 18 and 24 in text.)

[*Ascidia mollis* Alder and Hancock in Ann. Nat. Hist. (4) VI (1870), p. 358.]

Body ovate, lobulated, nearly black, attached by a small portion of the side at the lower half. *Apertures*, branchial terminal, anal from half to two-thirds down, rather inconspicuous. *Test* thick, smooth, and soft to the touch, rather shining, obtusely lobed, of a bluish or

Fig. 18.—*Ascidia mollis*. Natural size.

brownish black colour, showing some reddish veinings near the apertures. *Mantle* dark blue, with the apertures red. *Tentacular filaments* numerous, rather slender, varying in size, short, distant. *Branchial sac* with stoutish papillæ at the intersections of the meshes, and comparatively slender intermediate ones on the longitudinal bars. *Oral lamina* very narrow, strongly ribbed, and pectinated at the margin.

Length an inch and three quarters.

Hab.—[Below tide-marks?]

Ireland.—Birterbuy Bay, dredged (*Brady*), [and Kilkieran Bay (*More*), 1869,] Connemara, Galway.

First record.—Hancock, 1870; *coll.* Brady [1865].

Ascidia mollis is irregularly ovate, and is attached by a small portion of the side so that the extremities are free. The orifices are rather small and are slightly

protuberant or tubular; the branchial one is terminal and the anal more than half-way down the body, and at some distance from the ventral margin.

The test (Plate V, figs. 1–3, and figs. 18 and 24 in text) is of a blackish colour more or less tinged with brown or blue, it is thick, transparent, smooth, glossy, and soft to the touch, and is somewhat irregularly and obtusely lobed. The blood-channels (Pl. V, fig. 4) are numerous, the twigs being rather slender with the extremities much and suddenly enlarged, rounded, and of a crimson colour, dotting the surface all over with brilliant points, which are conspicuous towards the apertures; the twigs are pale crimson, the stems yellowish.

The mantle (Pl. V, figs. 5 and 6) is rather delicate and has numerous, fine, muscular fibres running in various directions, the transverse ones prevailing. The tubes are short, but distinctly developed, with the aperture red or crimson; the branchial one is exactly terminal, the anal is more than half way down the side, and is turned towards the dorsal margin.

The branchial sac (Pl. XVII, fig. 5) extends a little way behind the visceral mass and is minutely plicated; the primary vessels are rather distant and are pretty-regularly dispersed; the secondary vessels are long, and the stomata rectilinear with the extremities rounded. The longitudinal bars are stout; the papillæ at the intersections of the meshes are large and conical, the intermediate ones being more slender, but of nearly equal length; the papillary membrane is rather inconspicuous. The external vessels in connexion with the branchial ties and primary channels are well developed and form a reticulation at the outside of the sac or gill, and are studded all over with stoutish conical papillæ. The oral lamina (Pl. XIX, fig. 4) is much narrower than usual and is strongly ribbed on the right side; the left side is almost smooth; the margin is strongly pectinated. Below the mouth the lamina is so narrow that it is difficult to determine whether it is

pectinated or not, though the transverse ribs are conspicuous enough. The tentacular filaments of the branchial tube are nearly equal in size, rather short, and are widely separated from each other; only twelve were counted; but the specimen was probably imperfect in this respect.

The ovary is placed in the intestinal loop, and appears at the left side as a lobulated structure; a few lobules are also seen at the right side. The male cæca are probably quite minute, they are not observed at the surface, apparently being buried amidst the cellular matter, a thin coating of which is spread over the alimentary canal.

Var. **carnosa** *var. nov.* (Pl. V, figs. 7–11.)

A rosy flesh coloured variety of this species occurred, which may perhaps be specifically distinct; but if so colour alone will have to characterise it; for we cannot find any other feature of importance to distinguish it. The tentacular filaments, however, are more numerous, there being in the flesh-coloured variety about forty; while we have seen that the dark specimen examined has only twelve; but it is quite possible that, in this instance, some of them may have been removed, or that the specimen itself in respect to the tentacular filaments is abnormal.

Ireland.—Birterbuy Bay, Connemara (*Brady*).

8. **Ascidia plana** Hancock.

(Pl. VI; Pl. XVII, fig. 6; Pl. XIX, fig. 5; Pl. XX, fig. 6; and fig. 19 in text.)

[*Ascidia plana* Hancock in Ann. Nat. Hist. (4) VI (1870), p. 355.]

Body ovate, pellucid, yellowish horn-coloured, smooth, except at the orifices, which are tuberculated; attached by the lower half. *Apertures* not much produced; the branchial subterminal, the anal about half-way down. *Test* firm, rather thick, cartilaginous, smooth, hyaline,

with numerous blood-channels. *Mantle* rather delicate, with the apertures not much produced. *Tentacular filaments* closely set, numerous, rather stout and long. *Branchial sac* not quite so wide as the visceral mass, with short rounded papillæ at the intersections of the meshes, and small intermediate ones on the longitudinal bars. *Oral lamina* rather wide, ribbed, and pectinated.

Length upwards of two inches.

Hab.—[Below tide-marks ?]

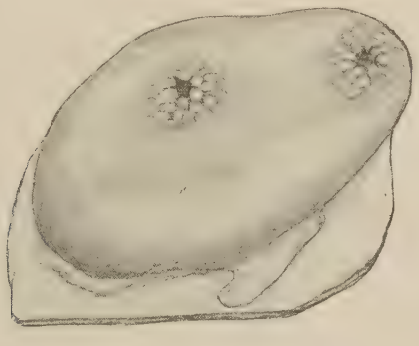


Fig. 19.—*Ascidia plana*. Natural size.

England.—Hastings, Sussex [,dredged] (*Bowerbank*).
Channel Islands.—Guernsey (*Alder*).

First record.—Hancock, 1870 ; *coll.* Bowerbank [1865].

The test of this very distinct species (fig. 19), which has probably been confounded hitherto with *A. mentula*, is thick, smooth, and firm, and the blood-channels (Pl. VI) can be distinctly observed in its hyaline, cartilaginous substance; they are of a yellowish flesh-colour, as seen in specimens in spirits, and are much subdivided, the terminal twigs being long and smaller so as to be fusiform; they are usually turned backwards; the extremities are rounded or only slightly pointed.

The mantle is rather delicate, and in preserved specimens exhibits in a remarkable manner the vascular reticulations filled with dark brown blood-corpuscles.

The branchial sac (Pl. XVII, fig. 6) extends a little below, and is rather narrower than, the visceral mass, which passes beyond its boundary in the dorsal region; it is minutely plicated. The primary vessels are rather distant and regular, and the stomata of the secondary vessels rather wide, somewhat irregular and short, with the extremities usually pointed. The longitudinal bars are rather stout, with the papillæ unusually short, broad, and rounded; they are alternately large and small, the latter being on the bars between those at the intersections of the meshes; and all have a hispid appearance, probably caused by the remains of cilia. The papillary membrane is distinct but limited in extent. The oral lamina (Pl. XIX, fig. 5) is well developed, and is strongly and closely ribbed on the right side, less strongly on the left; the margin is minutely pectinated, there being usually three or four small points on the membrane between those of the ribs which are larger and stronger than the rest. The lamina is smooth and little developed below the mouth. On the left side of the oral orifice the row of tentacular points is well defined; it consists of about thirty large, triangular, sharp-pointed, leaf-like processes. The branchial tubercle (Pl. XX, fig. 6) is small, and is a simple loop open in front. The tentacular filaments of the incurrent tube are about forty in number; they are of moderate length and rather slender, closely arranged in a single row and attached by the base for some little distance upwards. As a few of the smaller ones are more slightly attached than the rest, there is somewhat the appearance of an interrupted second or upper row of short filaments.

The ovary is a rather slender, branched organ, ramifying over the upper portion of the left side of the intestinal loop. The oviduct is seen as usual on the right side following the sinuosities of the intestine; it is a wide tube, the rounded proximal extremity of which, penetrating the intestinal loop, is seen at the left side where it becomes connected with the ovary.

In the same region small cæca have been observed, but they are very inconspicuous.

This species is evidently closely related to *A. Alderi*. The loop of the intestine, as in it, is placed crosswise, and the viscera are attached to the test by a membranous process which passes into the intestinal loop, just as a similar process does in that species. *A. plana*, however, is sufficiently distinguished by the number and arrangement of the tentacular filaments, the form of the branchial papillæ, and the character of the vascular ramifications of the test.

We have seen only two individuals of this species, and they had both been some time in spirit before they were examined; so with respect to colour little is known. But in consequence of the blood-corpuscles, which are very numerous, remaining of a dark brown colour, this is one of the best, if not the very best, species for the determination of the vascular system. The blood-channels can be traced on almost any part of the organism, even to their minutest ramifications.

9. **Ascidia Alderi** Hancock.

(Pl. XVII, fig. 7; Pl. XIX, fig. 6; and figs. 7 and 20 in text.)

[*Ascidia Alderi* Hancock in Ann. Nat. Hist. (4) VI (1870), p. 356.]

Body irregularly ovate or pyriform, produced towards the upper end, of a yellowish horn-colour inclining to flesh-tint, with a few small, scattered tubercles; attached diagonally by the base and about half way up the side. *Apertures* produced, distant, with longitudinal tuberculated ridges; the branchial aperture terminal, the anal about two thirds down the body, and inclined towards the left side; ocelli red. *Test* moderately thick, firm, transparent, with the terminal twigs of the blood-channels appearing

at the surface of a crimson colour; much enlarged and widely fusiform. *Mantle* rather delicate, with the apertures tubular, well produced. *Tentacular filaments* slender, distant, not numerous. *Branchial sac* narrower than the visceral mass, with papillæ at the intersections of the meshes and smaller ones on the bars between them, all having on each side a tubercular swelling. *Oral lamina* transversely ribbed and pectinated.

Length upwards of two inches.

Hab.—Between tide-marks.

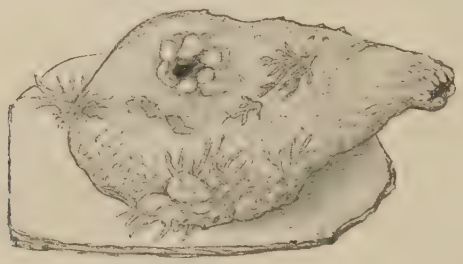


Fig. 20.—*Ascidia Alderi*. Natural size.

Channel Islands.—Herm, Guernsey (*Norman*).

First record.—Hancock, 1870; *coll.* Norman [1865].

We have had the opportunity of examining but one individual of this species, and as it had been for some time in spirit little can be said respecting its colour. All the other characters however were determinable; and they are sufficient to distinguish it from all known species.

The test (fig. 20) was a little affected with parasitic zoophytes; but the greater part of the surface was quite free, and exhibited with great distinctness the short, thick, deep crimson-coloured extremities of the blood-channels, which are very numerous and much subdivided; the terminal twigs are considerably enlarged and are pretty-regularly fusiform with the extremity mucronated. The larger branches are generally of a pale yellowish red.

The mantle is rather delicate, with the muscular fibres fine, and chiefly arranged transversely.

The branchial sac (Pl. XVII, fig. 7) extends a little below the visceral mass; it is minutely plicated; the primary vessels are pretty regular, and the stomata of the secondary vessels are rather long, with rounded extremities. The longitudinal bars are as numerous as the plications, and the papillæ are of moderate size, with the points rounded and produced some way in advance of the lateral tubercular projections, which give to them a shouldered appearance; thence the papillæ widen to the base; the small intermediate ones are formed exactly like the larger papillæ. The papillary membrane is distinctly developed. The oral lamina (Pl. XIX, fig. 6) is wide, and is divided in front much further down than usual; it is ribbed on the right side, and the margin is strongly pectinated, the points being much elongated immediately in front of the mouth, and increased in number, as here the pectinations, which are usually the produced extremities of the ribs, have others between them that originate in the membrane of the lamina itself. The tentacular points, of which there are about twenty-seven, on the left of the mouth, are large, wide, triangular, leaf-like processes. The branchial tubercle is small, and in the form of a simple loop open in front. The tentacular filaments (fig. 7) at the entrance of the branchial sac, are arranged in a single line, not on the usual muscular band, but apparently on a delicate fold of the lining-membrane; there are about twenty slender, not very long filaments placed considerably apart, with occasional short intermediate ones making in all about fifty.

The ovary is confined entirely to the left side of the intestinal loop; though the extremities of three or four of the branches pass so far round the upper margin of the intestine as to appear at the right side. The organ is composed of numerous, irregularly-contorted branches, some of which stray downwards as far as

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the stomach. The oviduct passes through the loop of the intestine, and its rounded extremity is seen on removing the lining-membrane; here it becomes united to the main branches of the ovary. The male cæca, which are minute, numerous, and branched, appear at the surface of the right side of the intestine; a few are also observed on removing the lining membrane on the left side.

This interesting species is closely related to *A. plana* as is proved by the transverse position of the intestinal loop, which is arranged exactly as it is in that species; and moreover the visceral mass is attached to the right side of the test by a membranous band which passes through the loop of the intestine in the same manner as it does in *A. plana*; the band being adherent to the lining-membrane at the left side of the intestine. It is nevertheless readily distinguished from that species by the arrangement of the tentacular filaments; by the form of the branchial papillæ; by the colour and peculiar character of the blood-channels of the test; and by several other minor features.

10. **Ascidia rudis** Alder.

(Pl. VII, figs. 1–4; Pl. XVII, fig. 8.)

Ascidia rudis Alder in Ann. Nat. Hist. (3) XI (1863), p. 155 [; Norman in Rep. Brit. Assoc. 1867 (1868), p. 439, and *op. cit.* 1868 (1869), p. 302].

Body oblong or ovate, rather irregular, depressed, greenish, attached largely by the side. *Apertures* distinct, the branchial terminal, the anal generally about half way down; ocelli red, uniform. *Test* thick, coriaceous, coarse, wrinkled, and very slightly tuberculated, sometimes nearly smooth. *Mantle* bluish-green, with a yellowish tinge towards the upper part, the apertures distinctly tubercular, the anal tube often much extended, and entering into a kind of sheath in the substance of the test. *Tentacular filaments* few and

slender. *Branchial sac* green, with stout papillæ at the intersections of the meshes, and frequently with intermediate ones on the longitudinal bars. *Oral lamina* transversely ribbed.

Length about two inches and a half.

Hab.—Between tide-marks [and at low-water mark].

England.—Hastings, Sussex (*Blackett* and *Bowerbank*).

Scotland.—Near the Whalsey Lighthouse, Out Skerries, Shetland [,1861, the type specimens] (*Norman*). [Between the Islands of Whalsey and Balta (*Norman*, 1867).]

Ireland.—Belfast Bay, Antrim (*Thompson*).

First record.—Alder, 1863 ; *coll.* Norman [1861].

The test (Pl. VII, fig. 1) is richly supplied with vascular ramifications, the ultimate twigs being very numerous and minute ; and the mantle (Pl. VII, fig. 2) is delicate, with few and irregularly-disposed muscular fibres.

The branchial sac (Pl. VII, fig. 3, and Pl. XVII, fig. 8) is minutely plicated, and the longitudinal bars correspond in number and direction to the plications, which are distinctly defined. The papillæ are large, obtuse, and somewhat arched, with well-developed intermediate small ones ; the larger are placed at the angles of the meshes formed by the bars crossing the primary vessels, and, as the meshes are rather small, the papillæ appear crowded, especially as the intermediate ones are of considerable size. The primary vessels are pretty regular in size, but there are a few larger at irregular intervals ; and on the outside of the sac, they and other vessels which proceed from them, chiefly at right angles, are strongly papillose. The oral lamina is moderately developed and has the right side ribbed, and the tentacular points, extending from the left side of the mouth downwards to the bottom of the sac, are much larger than usual, and are, for the greater portion of their length, free. The tubercle is

a simple loop, the convexity downwards, and with the right point a little prolonged, and there are about twenty slender tentacular filaments at the base of the incurrent tube, pretty-regularly large and small alternately. The nervous ganglion is nearly half way down the mantle and is almost concealed by the gland in connexion with it.

The ovary is a much branched and dendritic organ spread over the left side of the intestinal loop; and the male cæca are apparently confined to the same side, but are for the most part buried amidst the coating of cellular matter.

Ascidia rudis bears a great resemblance to *A. mentula* in many of its characters, and may have been passed over as a variety of that species. It differs, however, in size and colour, in bearing small distant tubercles, and in being much more largely attached. The anal orifice, too, is, in the mantle, placed at the end of a longish tube which enters into an internal sheath formed by a thickening of the test, and is very little produced outside; the external opening varying in position according to the length of the tube. In a variety from Hastings which we owe to the kindness of Mrs. Blackett, the tube is very much elongated within the test, and opens externally at a short distance from the branchial aperture. Usually, however, it is situated about halfway down the test, pretty near to the position that it occupies in the mantle. Some varieties of this species approach, in appearance, large specimens of *Ascidia depressa*.

11. **Ascidia venosa** Müller.

(Pl. VII, fig. 5; Pl. VIII, IX, X; and fig. 4 in text.)

Ascidia venosa Müller Zool. Dan. Prod. [1776], p. 225, no. 2736, and Zool. Danica, I [1788], p. 25, pl. xxv, f. 1–3; [Lamarck Anim. sans Vert. ed. 1, III (1816), p. 125; ed. 2, III (1840), p. 532; Bruguière] Vers, I [1789], p. 154, pl. lxv, f. 4–6, in Encycl. Meth.; [Thompson in Ann. Nat. Hist. (1) V (1840), p. 93;]

Forbes and Hanley Brit. Moll. I [1848], p. 31; Thompson Nat. Hist. Ireland, IV [1856], p. 359; [Alder in Rep. Brit. Assoc. 1866 (1867), p. 207; Norman in Rep. Brit. Assoc. 1868 (1869), p. 302].

Body elongated, sub-cylindrical, rather compressed, attached by the base. *Apertures*, branchial terminal, anal a short way down the side. *Test* cartilaginous, semi-transparent, smooth, thickly veined with red so as to appear uniformly of that colour. *Mantle* crimson, veined. *Tentacular filaments* stout and longish. *Branchial sac* with rather obtuse primary papillæ at the junction of the bars, and without secondary papillæ. [*Oral lamina* wide and closely ribbed.]

Length an inch to an inch and a half.

Hab.—Below tide-marks; 40–50 fathoms in the Shetlands.

England.—Hastings, Sussex (*Blackett* and *Bowerbank*).

Scotland.—Hebrides (*Forbes* & *Mc.Andrew* [; *Alder*, 1866]). Isle of Sky and Shetland (*Norman* & *Jeffreys*). [Middle Haaf off Out Skerries, and Haroldswick Bay, Shetland Islands (*Norman*, 1868).]

Ireland.—Strangford Lough, Down, and Belfast Lough, Antrim, dredged (*Thompson*). Killery Bay, Connemara, Galway (*Thompson*, *Ball*, and *Forbes* [1840]).

First record.—["First distinguished as an Irish species by Dr. J. L. Drummond" (*Thompson*, 1840); evidently the first British record.]

This beautiful species appears to be pretty-generally diffused. It has not yet been met with, however, on the east coast of England.

The soft pellucid rosy hue of the smooth test (Pl. VII, fig. 5) is very characteristic, and the deeper tone of the blood-channels when looked at with a hand-lens heightens the effect. These channels (Pl. VIII) are exceedingly numerous, and divide and subdivide until their extremities become quite microscopic. A flat

wedge-shaped process projects from the inner surface of the right side, and, penetrating into the loop of the intestine, holds the visceral mass firmly in its position. This process does not merely enter the loop, but is attached to the walls of the alimentary tube through the agency of the mantle (Pl. IX, fig. 1), which is a delicate membrane but sparingly supplied with muscular fibres.

The branchial sac (Pl. X) is more delicate than usual and is minutely plicated; the plicæ however in some of the specimens from Shetland are rather obscure and difficult to observe. The primary vessels are regularly arranged and pretty equal in size, a few only being a little larger than the rest; the secondary vessels are rather longer than usual and the stomata are widish, with the extremities somewhat pointed. The papillæ at the intersections of the longitudinal bars are stout, conical, and obtuse, with occasionally a few scattered, small, intermediate ones; the papillary membrane is strongly developed. The oral lamina (Pl. IX, fig. 2) is wide, with the right side rather closely ribbed; it reaches to the bottom of the sac and retains its width considerably below the mouth; a narrow lamina with denticulated margin extends from a little above the mouth on the left side to the lower extremity of the sac. The branchial tubercle (Pl. IX, fig. 2) is very minute and horse-shoe-like with the arch downwards. The tentacular filaments, of which there are between sixty and seventy, are arranged in a single line; they are long and slender, but vary considerably in length.

The ovary (Pl. IX, fig. 4) is a branched tubular organ ramifying over the left side of the intestinal loop, covering the whole of this portion of the alimentary tube with an open network of thickish contorted branches. The testis (Pl. IX, fig. 4) is largely developed, and is spread over the entire left side of the stomach and part of the intestine, covering a considerable portion of the other side of the alimentary tube

(Pl. IX, fig. 3); it is composed of a vast multitude of minute, obtuse, ramified cæca, crowded and packed together in much confusion.

12. **Ascidia producta** Hancock.

(Pl. XVII, fig. 9; Pl. XIX, fig. 7; and fig. 21 in text.)

[*Ascidia producta* Hancock in Ann. Nat. Hist. (4) VI (1870), p. 360.]

Body much elongated, pyriform, depressed, attached by its entire length, of a pale green colour. *Apertures* tubular, the branchial a little produced and turned towards the ventral margin, the anal three-fourths down near the ventral margin: ocelli red. *Test* rather thick, pellucid, cartilaginous, covered with minute, distant, conical papillæ. *Mantle* of a full dark green colour, delicate, with the branchial tube considerably produced and terminal; the anal short and turned backwards. *Tentacular filaments* numerous, slender. *Branchial sac* minutely plicated, with moderate-sized papillæ at the intersections of the meshes; secondary papillæ altogether wanting or rarely developed here and there. *Oral lamina* narrow, pectinated, ribbed, and tuberculated on the left side.

Length two inches and a half.

Hab.—At extreme low water and below tide-marks.

Scotland.—Hebrides [, dredged in the Minch] (*Norman*).

Ireland.—[Strangford Lough (*Norman*, 1869).]

First record.—Hancock, 1870; *coll.* Norman [1866].

The body of this species is wide behind, much elongated, and curved towards the ventral margin, narrow, tapering in front. It is attached throughout its entire length, and there is a thin, interrupted, marginal expansion, widening the area of attachment. The branchial tube is terminal, and unites imperceptibly with the tapering extremity of the body; it is turned

towards the ventral margin. The anal tube is three-fourths down, a little within the ventral margin; it is turned backwards and is so short that in the contracted state it appears merely as an eminence.

The test (fig. 21) is pellucid, thick, firm, and cartilaginous, of a yellowish horn-colour and sparsely covered with minute, sharply-defined, soft, conical papillæ, most conspicuous in young specimens. The blood-channels are not very much subdivided, and they terminate in rounded but not enlarged extremities.

The mantle is well supplied with delicate muscular fibres, tapers gradually and is very narrow in front, subsiding imperceptibly into the well-produced branchial tube. The anal tube is more than three-fourths

Fig. 21.—*Ascidia producta*. Natural size.

down the ventral margin, and is short and turned backwards.

The branchial sac (Pl. XVII, fig. 9) is long and narrow, tapering upwards, and extends very little backwards beyond the visceral mass; it is minutely and somewhat obscurely plicated. The primary vessels are rather closely set and variable in size, with a few much larger than the rest at distant intervals. The stomata are short and rectilinear, with the extremities obtuse. The longitudinal bars are stout, with papillæ only at the intersections of the meshes; the papillæ are rather long and slightly shouldered, with the apices pointed and a little produced. The papillary membrane is obsolete. The oral lamina (Pl. XIX, fig. 7) is rather narrow, dies out a little below the mouth, and is succeeded by a few minute transverse ridges which

are continued to the bottom of the branchial sac. It is ribbed pretty-closely on the right side, and has the margin strongly pectinated; the points vary in size, the larger ones are in continuation of the ribs, the smaller, of which there are one or two between the larger, originate in the membrane itself: the left side is covered with large, curved, pointed papillæ, arranged for the most part in transverse rows: the tentacular points on the left side of the mouth are minute; they form a continuous series from a little above the mouth to the bottom of the branchial sac. The branchial tubercle is loop-formed with both extremities turned to the left side. The tentacular filaments are numerous, slender, and of moderate length; they do not vary in size and are rather closely set.

The ovary is branched and tubular; a few of the terminal branches appear at the end of the intestinal loop on the right side, but the greater portion of the organ ramifies over the inner margin of the loop on the left side, where the branches become united to the extremity of the wide oviduct, which, penetrating the loop, appears at this side. The male cæca are long, sometimes a little branched, and usually bifid; they are spread over the right side of the intestine, but are somewhat obscured by the cellular matter which coats the alimentary tube. There are a few cæca also at the other side of the intestine.

Ascidia producta evidently belongs to that group of which *A. inornata* and *depressa* are typical; but has many characters to distinguish it from all others. Three or four mature individuals were procured; but, as they had all been for some time in spirit before being examined, their colour could not be determined satisfactorily. A few young specimens, however, which had been preserved in a weaker spirit, retained their original colour. In these the test was of a fine, pale green, and the mantle and viscera of a full, dark green. Mr. Norman thinks that the mature specimens, when taken, were also of a green colour.

13. **Ascidia inornata** Hancock.

(Pl. XVII, fig. 10; and fig. 22 in text.)

[*Ascidia inornata*, Hancock in Ann. Nat. Hist. (4) VI (1870), p. 359.]

Body elongated, oval, depressed, attached by the whole side, of a watery horn-colour. *Apertures* a little produced, with longitudinal ridges or folds; the *branchial* sub-terminal, the *anal* about half way down. *Test* rather thin, cartilaginous, transparent, with a few minute papillæ and some scattered agglutinated particles of sand and shells, chiefly towards the border

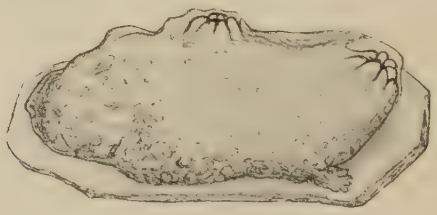


Fig. 22.—*Ascidia inornata*. Natural size.

of attachment. *Mantle* well supplied with interwoven muscular fibres. *Tentacular filaments* numerous and rather stout. *Branchial sac* narrow, with large papillæ at the intersections of the meshes, and small intermediate ones on the longitudinal bars. *Oral lamina* wide, strongly ribbed; margin pectinated and bordered on the left side with a band of tubercles.

Length nearly two inches.

Hab.—?

England.—Hastings, Sussex (*Bowerbank*).

First record.—Hancock, 1870; *coll.* Bowerbank.

We have seen only a single individual of this species, and, as it had been some time in spirit before it was examined, not much is known respecting its colour.

The test (fig. 22) is thin, firm, and elastic, and of a transparent watery horn-colour, with a few very minute, scattered papillæ, and here and there, spread over the

surface, are some adherent particles of sand and shells, which become accumulated towards the border of the attachment. It is somewhat depressed, is attached by the entire side, and there is an irregular, thin, marginal expansion. The apertures are slightly tubular, with smooth longitudinal folds or plaits; the branchial, being turned towards the free or upper side, is subterminal: the anal is a little more than half way down the ventral side. The blood-channels are of a pale yellow colour, much branched and pretty-evenly distributed over both the external and internal surface of the test. The main branches are large, and the extremities of the terminal twigs are rounded but not enlarged.

The mantle is narrower than the visceral mass and projects very little backwards beyond it. The muscular fibres are well developed, and are interwoven; the longitudinal and diagonal ones are inconspicuous, but the transverse are the most numerous and are closely netted. The tubes are short, but rather wide; the anal, projecting from the ventral margin a little more than half way down, is turned forward; the branchial is turned a little upwards or towards the left side.

The branchial sac (Pl. XVII, fig. 10), which, like the mantle, is not so wide as the visceral mass, at least as it appears in the contracted state, extends backwards very little beyond the stomach. It is minutely plicated; the primary vessels are rather distinct, nearly equal in size, and regularly disposed; the stomata are rather long, rectilinear, with the extremities usually a little pointed. The papillæ of the intersections are large and unusually long, with the sides almost parallel; but are shouldered near the summit and have their apices rounded. There are intermediate tubercles on the longitudinal bars, which, though very much smaller, are of the same peculiar form as the primary. The papillary membrane is moderately developed. The oral lamina is wide and strongly ribbed on the right side,

and less strongly on the left; the margin is strongly pectinated, with one or more points on the membrane between those of the ribs which are large and stouter than the rest. The margin on the left side is bordered with a rather wide band of large, curved, pointed, papillæ; they are mostly irregularly disposed, but the largest, which are the lowest down, are arranged with considerable order in a double row. Near the mouth they are much crowded. The belt of tentacular points on the left side of the mouth is advanced for some little distance in a straight line upwards; in all there are about twenty rather large points. Below the mouth the oral lamina gradually dies out and is succeeded by a few minute diagonal plaits or folds. The branchial tubercle is looped-formed, with the left extremity turned outwards. The collar of tentacular filaments is placed very little in advance of the branchial margin; they are numerous, closely-set, rather stout and long, with their bases adherent to the mantle for some distance upwards; a few smaller ones are interspersed, which, bending forward in front of the others, give somewhat the appearance of an anterior or second row.

The ovary is confined to the left side of the alimentary tube; it is composed of ramified tubes which are spread over the inner margin of the intestinal loop, forming there a small patch of involved branches. The male cæca are wide and obtuse, frequently irregularly lobed, but usually bifid; they coat the greater portion of the right side of the alimentary tube, but do not extend to the posterior extremity of the stomach. The cells spread over the visceral mass are large, with a dark conspicuous nucleus in each.

A. inornata is allied to *A. plebeia*, but differs from it in many respects, and may at once be distinguished by the narrowness of the mantle and branchial sac, and likewise by the characters of the branchial papillæ and oral lamina.

14. **Ascidia depressa** Alder and Hancock.

(Pl. VII, figs. 6–8; Pl. XVII, fig. 11; Pl. XIX, fig. 8.)

Ascidia depressa Alder and Hancock in Trans. Tyneside Nat. Field Club, I [1848], p. 201; Forbes and Hanley Brit. Moll. II [1849], p. 273 [; Alder in Rep. Brit. Assoc. 1866 (1867), p. 208; Norman in Rep. Brit. Assoc. 1868 (1869), p. 302].

Body oblong-ovate, very much depressed, pale green, attached laterally throughout its entire length by a distinct expansion or disc surrounding the whole. *Apertures* distant with small red ocelli; the branchial aperture terminal, the anal on a slight bulging about two thirds down, rather inconspicuous. *Test* transparent, granular or minutely tuberculated on the upper surface, and thickened towards the disc; under or attached side smooth and very thin. *Mantle* yellowish green; of a deeper colour inclining to orange on the lower part. *Tentacular filaments* numerous, in more than one row. *Branchial sac* with obtuse papillæ. [*Oral lamina* wide, ribbed on the right side.]

Length about an inch.

Hab.—Attached to the under-side of stones between tide-marks (and sometimes extending to deep water?).

England.—Common on the north-eastern coast. [Falmouth, Cornwall (*Cocks*, 1849).] Isle of Man (*Alder*).

Scotland.—Hebrides (*Alder*, 1866). [Island of Housay, Out Skerries, Shetland, at low water (*Norman*, 1868).]

Ireland.—Connemara, Galway (*Brady*).

First record.—Alder and Hancock, 1848.

The test of this species (Pl. VII, fig. 6) exhibits numerous blood-channels, the ultimate twigs of which are minute, and have their extremities rounded, but not enlarged. In old specimens the tubercles sometimes become nearly obliterated and the surface is strongly wrinkled.

The mantle (Pl. VII, figs. 7 and 8) is thin and delicate, with the muscular fibres fine and for the most part transverse and diagonal.

The branchial sac (Pl. XVII, fig. 11) extends the whole length of the body, and is minutely plicated, and the secondary vessels are rectilinear, with the extremities of the vessels obtuse; the primary vessels are pretty equal in size, and the longitudinal bars somewhat more numerous than the plications. The papillæ are alternately large and small; with rounded extremities, and the membrane in connexion with the larger ones or those at the intersections is moderately developed. The oral lamina (Pl. XIX, fig. 8), which is rather wide, is ribbed on the right side, and the smooth or left side has a row of minute papillæ just within the free margin, extending from one end to the other; sometimes the papillæ are double. The tentacular points on the left side of the mouth are rather large. The tubercle in front of the lamina is horse-shoe formed, with the limbs turned forwards. The tentacular filaments are very numerous, long, and much crowded; they are arranged in a broadish belt, having the smaller in front, the larger behind, so that there seem to be two or three rows of them.

The ovary appears on both sides of the intestinal loop, but is most extensively developed on the left side, where it assumes the form of a complicated entanglement of small and contorted branches. The cells covering the stomach are large.

15. **Ascidia elongata** Alder & Hancock.

(Pl. XVII, fig. 12.)

[*Ascidia elongata*, Alder & Hancock in Ann. Nat. Hist. (4) VI (1870), p. 360.]

Body elongated, slender, transparent, nearly colourless, attached slightly at the side of the base; the *branchial aperture* terminal, the *anal* about two-thirds down. *Test* hyaline, minutely tuberculated, the tuber-

cles rather distant and pointed. *Tentacular filaments* numerous, long, and slender. *Branchial sac* with obtuse primary but no secondary papillæ, the stomata elliptical. *Oral lamina* smooth, ribbed, rather narrow.

Length about two inches; breadth about half an inch.

Hab.—Deep water?

England.—Seaham Harbour (*Hodge*).

First record.—Hancock, 1870; *coll.* Hodge.

The test of this species is extremely hyaline, and contains numerous blood-channels, which are minutely subdivided, the ultimate twigs terminating in rounded extremities.

The mantle is well supplied with delicate muscular fibres, transverse, longitudinal, and diagonal; but they are not arranged with much order.

The branchial sac (Pl. XVII, fig. 12) is long and narrow, extending the whole length of the body; it is minutely plicated; the plicæ are, however, so shallow and obscure that they might easily be overlooked, but, on examining the outside of the sac, they are obvious enough. The primary vessels are pretty regular; but the secondary vary considerably, some being very wide, others comparatively narrow, arising from the irregularity of the stomata which not only vary in size but also in form. They are usually wide and short, frequently sharply pointed at the ends, and sometimes with one end pointed and the other rounded, so as to have an elongated ovate form; some extend almost the whole breadth of the space between the primary vessels, others not half that space; their width, form, and irregularity being very characteristic. The papillæ on the longitudinal bars where they intersect the primary vessels resemble those of *A. aculeata*; but they are shorter, thicker, more obtuse, and the lateral tubercles are less prominent; the papillary membrane, also, is more extensively developed, and there are no intermediate small papillæ. The oral lamina is rather

narrow, and is ribbed on the right side: the tubercle is minute, and in the form of a loop open in front; the extremities are pointed. The tentacular filaments are very slender, long, and numerous; they do not vary much in length and are closely set in a single line, but have in front a few quite short filaments. The oral lamina has the fringe of tubercular points on the left of the mouth well developed, the free points being rather large.

The ovary is situated on both sides of the intestine, but chiefly on the left side towards the upper extremity of the loop; it is a rather delicately-branched organ, so arranged as to have the appearance of an open reticulation. The male cæca are very minute, and are placed on the left side of the intestine and stomach; but it must be observed that in the specimen examined the reproductive organs were not fully developed. The cells coating the stomach are large.

This species is evidently related to *A. aculeata*, but it is distinguished by many characters. Besides the very elongated form, the attachment is different and the test only slightly tuberculated. The tentacular filaments are differently arranged, and the minute structure of the branchial sac is quite peculiar and alone sufficient for specific distinction.

16. **Ascidia aculeata** Alder.

(Pl. VII, figs. 9–11; Pl. XVIII, fig. 1; Pl. XIX, fig. 9.)

Ascidia aculeata Alder in Ann. Nat. Hist. (3) XI [1863], p. 156.

Body ovate, depressed, greenish, attached more or less by the side to sea-weeds or zoophytes. *Apertures* nearly sessile, aculeated, the branchial terminal, the anal one-third down the side. *Test* thin, transparent, greenish or nearly colourless, covered with aculeated tubercles most prominent on the upper or left side. *Mantle* greenish, transparent, showing the reticula-

tions of the branchial sac and sigmoid intestine. *Tentacular filaments* numerous, long, and slender. *Branchial sac* with large primary and also secondary papillæ, the stomata long and rectilinear. [*Oral lamina* ribbed on the left side.]

Length an inch to an inch and a half.

Hab.—From between tide-marks to deep water.

England.—Tor Bay, Devon (*Alder*).

Scotland.—Lamlash Bay, Arran (*Carpenter*).

Ireland.—Strangford Lough, Down (*Thompson*). Connemara, Galway (*Brady*). Bantry Bay, Cork (*Norman*).

Channel Islands.—Guernsey (*Norman*).

First record.—Alder, 1863 [; *coll.* "many years ago"].

The test (Pl. VII, fig. 9), which is thin, firm, and transparent, is richly supplied with vascular ramifications, the minute terminal twigs having their extremities simply rounded.

The muscular fibres of the mantle (Pl. VII, fig. 10) are not very numerous and are irregularly disposed.

The walls of the branchial sac (Pl. VII, fig. 11, and Pl. XVIII, fig. 1) are minutely plicated, and the secondary vessels are rather long, the stomata being elongated and rectilinear with rounded extremities; the primary vessels are comparatively delicate, and placed further apart than usual. The longitudinal bars are rather more numerous than the plications, and they support at the intersections large, conical papillæ, generally with small ones between them; towards the apex of each papilla, which is rounded, there is at either side a prominent tubercle, below which the papillæ widen downwards to the base. The extremities of the papillæ, moreover, are curved downwards or involuted, and thus the profile is fiddle-head-shaped; the papillary membrane is not largely developed. The oral lamina (Pl. XIX, fig. 9) is wide with the right side ribbed, and the margin of the left or smooth side is minutely and

irregularly tuberculated. The tubercle in front of the oral lamina is small and horse-shoe-like, with the extremities rounded and turned upwards. The tentacular points at the left side of the mouth, and those in continuation of the oral lamina downwards on the other side, are few and very large. The tentacular filaments are arranged in a widish, crowded collar, in which they are small in front, and long and slender behind.

The principal portion of the ovary is spread over the left side of the intestine; there are a few branches, however, at the upper part of the loop on the right side. It is composed of numerous, irregular, and somewhat confused ramifications of no great size. Male cæca appear on both sides of the alimentary tube, but are most numerous at the right side, where they extend to the stomach, over which there is a coating of large cells.

This species comes nearest to *A. depressa*, but is less depressed, less loosely attached, and without the marginal disc dividing the upper from the under surface. The test is more uniformly thin, and has stronger and more sharply-pointed tubercles. The apertures are also less distant. The tubercles are frequently compound, bearing several aculeations. This is probably the "*Ascidia mamillaris*, Delle Chiaje," of Thompson's 'Natural History of Ireland,' but we think not of Delle Chiaje, judging from his figure.

17. **Ascidia amœna** *sp. nov.*

(Pl. XI, figs. 1 and 2; Pl. XVIII, fig. 2.)

Body oval, semitransparent, greenish, largely attached by the right side; the upper slightly gibbous. *Branchial aperture* a little way down the side, tubular; *anal* about two thirds down, not very prominent. *Test* transparent, nearly colourless, thickly covered with stout, conical tubercles, generally with one, sometimes with two, small papillæ at the apex. *Tentacles*

numerous, long, and slender. *Branchial sac* minutely laminated, with broad, stout, conical papillæ at the intersections of the meshes, and smaller intermediate papillæ. *Oral lamina* with the right side ribbed, and lobed or widened over the mouth.

Length about an inch.

Hab.—Deep water.

England.—Seaham Harbour, Durham (*Hodge*).

Channel Islands.—[Guernsey] (*Norman*).

First record.—Hancock [; *coll.* Norman, 1870].

We have seen only two individuals of this rather critical species (Pl. XI, figs. 1 and 2); it is undoubtedly closely allied to *A. aculeata*, from which it is chiefly distinguished by the more simple character of the external tubercles (Pl. XVIII, fig. 2), which occasionally support two papillæ or spines, but usually only one, while in *A. aculeata* they bear several aculeations. The branchial papillæ, also, differ considerably in the two species; they are more pointed in *A. amœna* than in *A. aculeata*; and in the former there is on either side near the base a tubercular swelling; but similar swellings in the allied species are close to the apex; in the former, too, the profile view of the papillæ is more squat and not so decidedly fiddle-head-shaped as it is in *A. aculeata*. The ovary is very similar in both species.

18. **Ascidia plebeia** Alder.

(Pl. XI, figs. 3–5; Pl. XVIII, fig. 3.)

Ascidia plebeia Alder in Ann. Nat. Hist. (3) XI [1863], p. 155 [, and Rep. Brit. Assoc. 1866 (1867), p. 207; Norman in Rep. Brit. Assoc. 1868 (1869), p. 302].

Body oblong, slightly scabrous, attached for nearly the whole length, greenish. *Apertures*, branchial terminal, produced, conical; anal about two-thirds down, slightly raised; ocelli small, red. *Test* thin, transparent, roughish, with small papillæ and sparsely

covered with fragments of shells and sand, especially towards the attached part. *Mantle* yellowish green. *Tentacular filaments* numerous and stout. *Branchial sac* with papillæ at the intersections of the meshes, and occasionally small intermediate ones on the longitudinal bands or bars. *Oral lamina* plicated on the right side.

Length.—An inch and a half to two inches.

Hab.—Deep water.

England.—Mr. Alder has met with one or two *Ascidiæ* from the coasts of Northumberland and Durham which we are inclined to refer to this species.

Scotland.—[Hebrides (*Alder*, 1865).] Outer Haaf, Shetland, dredged (*Norman & Jeffreys*). [Forty miles east of Whalsey Lighthouse, 1861, the type specimens (*Norman*, 1868).]

First record.—Alder, 1863 [; *coll.* Norman & Jeffreys, 1861].

The test of *A. plebeia* (Pl. XI, fig. 3), which is rather thin, soft, and transparent, is amply supplied with blood-channels, the terminations of the small branches being slightly enlarged and rounded. The mantle is delicate and is but scantily provided with muscular fibres which are scattered and irregularly disposed.

The primary vessels of the branchial sac (Pl. XI, fig. 4, and Pl. XVIII, fig. 3) are pretty regular in size and arrangement, and the secondary have the stigmatic meshes rather large. The minute plications of the vascular web are wide and shallow, and there is usually a longitudinal bar corresponding to each plication. The reticulation formed by the bars and the primary vessels is rather coarse and nearly equilateral, and the papillæ which are at the intersections are consequently somewhat distant; they are large, conical, and obtuse; there are also here and there minute papillæ on the bars between the large ones, and the membrane in connexion with the latter is rather limited in extent. The oral lamina is widish, and the ribs,

which are not numerous, are confined to the right side; it dies out rather abruptly immediately behind the mouth; the margin is entire. The tubercle is remarkably minute and forms a simple loop with the convexity turned downwards, but the left extremity is occasionally bent inwards. The tentacular filaments, which are long, stout, and pretty equal in size, are very numerous and crowded, and are arranged in a single series forming a regular collar.

The ovary is a rather delicate, dendritic organ, and ramifies over both sides of the intestinal loop, but the greater portion is at the left side, and though the ramifications are spreading they do not reach so far downwards as the stomach. The minute cæca of the male organ appear to be confined to the right side of the alimentary tube; at least, none were observed on the other side. The species is also remarkable for the large size of the cells coating the stomach, as similar cells do in all the members of the genus.

This species has affinities with *A. aculeata* and *A. depressa*. From the first it may be known by its more elongated form and more prominent apertures, and by the papillæ of the test being smaller, fewer, and not echinated; from the latter by its thinner test and smaller area of attachment, as well as by the absence of the thickened margin or disc which divides the upper from the lower surface in that species; and from both it may be distinguished by the fragments of shells with which it is usually more or less covered.

19. **Ascidia sordida** Alder and Hancock.

(Pl. XI, figs. 6 and 7; Pl. XII; XIII; XVIII, fig. 4; Pl. XX, fig. 7; and fig. 2 in text.)

Ascidia prunum Macgillivray, Moll. Aberdeen [1843], p. 312.

Ascidia rustica Dalyell Rare Anim. Scotland, II [1848], p. 143, pl. xxxiv, fig. 6; pl. xxxv (young?).

[Non *Ascidia prunum* Müll. nec *A. rustica* Müll. Zool. Danica (1788).]

Ascidia sordida Alder and Hancock in Trans. Tyneside Nat. Field Club, I [1848], p. 199; Forbes and Hanley Brit. Moll. II [1849], p. 372; [Alder in Nat. Hist. Trans. Northumb. and Durham, I (1865) p. 11; Norman in Rep. Brit. Assoc. 1868 (1869), p. 302].

Body longitudinally ovate, of a semi-transparent yellowish white, generally blotched with red, nearly smooth, but with an uneven surface, and rather rugose towards the apertures; attached by a narrow base. *Apertures* terminal and not far apart, slightly tubular, more or less echinated or tuberculated; ocelli small and inconspicuous. *Test* (Pl. XI, fig. 6) transparent, vitreous and colourless, with a few longitudinal wrinkles, rather tough, and very slightly contractile. *Mantle* yellowish, usually blotched and spotted with crimson on the upper part. *Tentacular filaments* slender [, alternately large and small]. *Branchial sac* with rather small papillæ. *Oral lamina* smooth.

Length an inch and a half to two inches.

Hab.—In the Coralline zone, N.E. England, usually attached to zoophytes [; in deep water, on dead shells, N.E. Scotland; on sandy ground, Shetland].

England.—On the north-east coast. Cullercoats, Northumb., plentiful. [Falmouth, Cornwall (*Cocks*, 1849).]

Scotland.—On the north-east coast. Firth of Forth (*Dalyell*). Aberdeen (*Macgillivray*). Wick, Caithness (*Peach*). Shetland (*Norman & Jeffreys* [; *McAndrew & Forbes*]). [East of the Isle of Balta, Shetland (*Norman*, 1868).]

First record.—Alder and Hancock, 1848 (Macgillivray, 1843, as *Ascidia prunum*).

The mantle (Pl. XI, fig. 7, and Pl. XII, fig. 1) of *A. sordida* is rather stout and is of a pale transparent yellow colour, usually with scattered circular spots or blotches of crimson towards the upper part; and freckled with opaque white, sometimes thickly accumulated so as almost to obscure the alimentary tube,

and there is generally a large oval white spot between the tubes concealing the ganglia. The tubes are short and conical; the branchial one is exactly terminal, the anal is placed near to it a little way down the ventral margin. The muscular fibres are interwoven on the left side; on the right side a few fibres pass inwards from the margins, particularly from the bases of the tubes.

The branchial sac (Pl. XII, fig. 2, and Pl. XVIII, fig. 4) is co-extensive with the mantle, both terminating near to the posterior margin of the visceral mass. It is minutely plicated; the primary vessels are numerous, regularly disposed, and a little variable in size; the stomata are somewhat elliptical, with the extremities pointed. The longitudinal bars are stout, with rather small obtuse papillæ at the intersections; there are no small intermediate ones. The papillary membrane is distinctly developed, though not conspicuously so. The oral lamina (Pl. XII, fig. 2) is wide and smooth, and terminates at the right side of the mouth, which is situated near the bottom of the branchial sac, usually in the midst of a large irregular red blotch which extends to the extremity of the lamina: there are no tentacular points on the left of the mouth. There are between fifty and sixty tentacular filaments arranged in a single line. The branchial tubercle (Pl. XII, figs. 2 and 3, and Pl. XX, fig. 7) is oval, placed lengthwise with the extremities of the loop usually turned towards the endostyle, though sometimes they are both incurved.

The ovary (Pl. XII, fig. 3, and Pl. XIII, fig. 1) is situated at the left side of the visceral mass; it is branched in a radiating manner from the centre of the intestinal loop, the branches extending over the whole of this portion of the alimentary tube. The male cæca (Pl. XII, figs. 1 and 4; and Pl. XIII, fig. 9) are large, numerous, irregularly lobulated or branched, and frequently bifid, with the extremities obtuse. They are distributed over both sides of the looped portion of the intestine, but on the right (Pl. XII, fig. 1) are most

conspicuous, and have a beautiful dendritic appearance, their white colour contrasting well with the brown tint of the cellular matter which is spread over the greater portion of the alimentary tube: the cells of this matter are moderately large.

This is the most common species on the north-east coast of England, where it is brought in abundantly on the fishermen's lines, frequently in groups of several together. They are usually attached to *Gemellaria loriculata* or some other zoophyte, and in the young state frequently cover it like a cluster of grapes. A group of this kind is represented by Sir John G. Dalyell in Plate XXXV of his 'Rare and Remarkable Animals of Scotland.' When young they are hyaline and almost colourless. From the narrowness of the base of attachment the individuals have not always room to expand; in this case the lower part of the test is lengthened with a flat pedicle sometimes as long as, or even longer than, the body of the animal. *Modiolaria marmorata* is often found imbedded in the test.

Mr. Norman informs us that when dredging in 73 fathoms water off North Uist in Shetland, a large dredge came up filled with *Ascidia sordida*, in such quantities that some hundredweights of them had to be thrown back into the sea.

20. **Ascidia canina** Müller.

(Pl. XVIII, fig. 5; Pl. XX, fig. 8.)

Ascidia canina Müller Zool. Dan. Prod. [1776], p. 225, no. 2734, and Zool. Danica, II [1788], p. 19, pl. lv, f. 1–3; [Bruguière] Vers, I [1789], p. 152, pl. lxiv, f. 1–3, in Encycl. Méth; [Thompson in Ann. Nat. Hist. (1) XIII (1844), p. 434;] Forbes and Hanley Brit. Moll. I [1848], p. 31; Thompson Nat. Hist. Ireland, IV [1856], p. 360; [McIntosh in Proc. R. Soc. Edinb. V (1866) p. 605].

Phallusia canina Savigny Mém. Anim. sans Vert., pt. 2 [1816], p. 171.

Body elongated, subcylindrical, rather soft, adhering at the base by fibrous prolongations of the test.

Apertures red, tuberculated or echinated longitudinally, the branchial terminal, the anal on a short tube at a little distance below. Ocelli inconspicuous. *Test* thin, sub-pellucid, yellowish white or horn-coloured, with a tinge of red, finely hispid, minutely but irregularly tuberculated and a little aculeated at the upper part. *Mantle* red above and yellowish below, the intestine, shining through, of a greenish colour. *Tentacular filaments* short. *Branchial sac* with small papillæ. *Oral lamina* with a strong smooth plait.

Length three or four inches.

Hab.— ?

England.—Solent Channel, Hants (*James* and *Forbes*). [Falmouth, Cornwall (*Cocks*, 1849).]

Scotland.—North Uist, Outer Hebrides (*McIntosh*). Kirkwall Bay, Orkney (*Forbes* and *Goodsir*).

Ireland.—Strangford Lough, Down (*Thompson*). Clew Bay, Mayo (*Thompson*, *Ball*, and *Forbes*).

First record.—Thompson [1844].

The blood-channels enter the test near to its base, and are confined to the lower portion, where there are a few large trunks which give off a limited number of slender branches, but none of them reach halfway up the test, and the alternate twigs end in slightly-enlarged elliptical cæca.

The mantle is very delicate, transparent, and but feebly supplied with muscular fibres, which are irregularly disposed.

The branchial sac (Pl. XVIII, fig. 5) is long and extends to the bottom of the mantle, and has the alimentary tube on the right side. The loop of the intestine is considerably elongated in the upward or antero-posterior direction, and the rectal portion is rather long and wide. The branchial membrane is rather delicate and minutely plicated; the primary vessels do not vary much in size, and are pretty regularly disposed. The longitudinal bars stand well up from the surface and are rather far apart, there

being usually a bar corresponding to every second fold of the respiratory membrane. The meshes formed by the bars crossing the primary vessels are much wider than long; the papillæ at the intersections are short and obtuse and the papillary membrane is narrow. The rectilinear stigmata of the secondary vessels are rather long. The oral band is well developed, and is for the most part smooth, but is imperfectly ribbed in the vicinity of the mouth. The branchial tubercle (Pl. XX, f. 8) is rather large and strongly involuted, and there are seventeen or eighteen moderately long, equal, delicate, tentacular filaments a little above the entrance of the branchial sac.

The reproductive organs are placed on both sides of the alimentary tube, but the ovary, which is a large, dendritic and folliculate organ, is arranged round the margin of the intestinal loop and sends ramifications to both sides of it. The testicular cæca are of the usual form, but are extremely minute; they are distributed over each side of the intestine. The *vas deferens* and oviduct are seen on the right side following the contortions of the intestine, and both terminate close to the anal orifice.

21. **Ascidia obliqua** Alder.

(Pl. XI, fig. 10; Pl. XVIII, fig. 6.)

Ascidia obliqua Alder in Ann. Nat. Hist. (3) XI [1863], p. 154.

Body broadly ovate, light horn-coloured, rather rugose when old, but not tuberculated, nearly smooth when young, attached diagonally at the base and partially at the side, leaning over towards the dorsal aspect. *Apertures* not far apart, tubes conical, with longitudinal grooves corresponding to the angles of the lobes; the branchial not quite terminal, the anal median. Ocelli inconspicuous. *Test* rather thin, transparent, sometimes a good deal covered with zoophytes. *Tentacular filaments* slender. *Branchial sac* with large, subclavate, papillæ. *Oral lamina* transversely ribbed

Length about two inches.
Hab.—Deep water.

Scotland.—Outer Haaf, Shetland [the type specimens], dredged in from 40 to 50 fathoms [; between the islands of Whalsey and Balta, Shetland, in about the same depth of water] (*Norman*).
First record.—Alder, 1863; *coll.* Norman [1861].

Three examples of this species were obtained by Mr. Norman in different stages of growth, the largest measuring a little above two inches in length. A somewhat larger specimen was sent to us from Sweden by Professor Lovén, with the name of *Ascidia mentula* attached. *A. obliqua* has probably hitherto been overlooked as a variety of that species, but it is perfectly distinct; the form is more ovate, the test very much thinner and attached obliquely at the base, the apertures are more distinctly grooved, and the branchial sac has not the intermediate papillæ, nor is it reflected upwards at the base, as in *A. mentula*. It appears to be a northern species.

The test (Pl. XI, fig. 10) does not appear to be well supplied with blood-channels, as is the case in *A. mentula*, and the branchial sac (Pl. XVIII, fig. 6) is minutely and obscurely plicated longitudinally, the plicæ being wide and shallow; there seem to be two or three longitudinal bars to each plait. The papillæ, which are large, with the extremity rounded and a little enlarged, are not numerous, the reticulations formed by the bars crossing the primary vessels being rather coarse, and the papillary membrane not nearly so extensively developed as is usual. There are about seventeen slender, distant, tentacular filaments, with a few small intermediate ones. The oral lamina is broad, with the right side delicately ribbed, the ribs being rather distant; and the branchial tubercle is broad and loop-formed, with the concavity turned upwards. The right hand extremity is a little bent outwards.

22. [**Ascidia Morei** *sp. nov.**]

(Pl. XIV, and fig. 23 in text.)

[*Body* ovate, of a pellucid yellow colour blotched with red, attached by a rather broad base. *Apertures* sessile or slightly tubular, near together, turned a little to the left side, the branchial nearly terminal, the anal a little way down towards the ventral margin. *Test* rather thick, firm, cartilaginous, transparent, colourless, wrinkled delicately lengthwise and minutely punctate. *Mantle* rather stout, semi-transparent, speckled with opaque white powder, the tubes and the upper extremity suffused with carmine. *Tentacular filaments* numerous, long and slender, of nearly equal size, dotted with opaque white. *Branchial sac* with strong rods, the papillary membrane rather contracted, the upper border, at its junction with the rod, abruptly enlarged. *Oral lamina* wide, margin entire, ribbed at the base of the right side.

Length about three quarters of an inch.

Hab.—Deep water ?

Ireland.—North Wall, Dublin, cast ashore (*More*).

First record.—Hancock ; *coll.* More, 1870.

The minute punctations of the test (Pl. XIV, figs. 1 and 2) give to the outer surface of this species a granular appearance, seen only with a powerful lens. The blood-channels are few, and are principally confined to the lower extremity.

The red spots on the mantle (Pl. XIV, figs. 4 and 5) are occasionally confluent, forming a brilliant carmine blotch extending over the greater portion of the pallial lobe. On both sides there is a delicate powder of

* This is the last species which Mr. Hancock examined. It is not described in the MS., having been collected after he had ceased to work at that. The description is drawn up from the pencil notes by the side and at the back of his drawings, where he has recorded the date of collection, 23rd October, 1870, and the date of his microscopical examination of the specimens, 27th April, 1871.

opaque white. The muscles are strongly developed and glisten amidst the spots of colour. The oral lamina (Pl. XIV, fig. 6) has the cleft in front short; it is widened a little at the mouth and terminates rather abruptly immediately below it. Above the mouth, on the left side, there are three or four oblique plaits; there is no denticulation at the side. It is usually more or less coloured with brilliant carmine, particularly at the base and in the vicinity of the mouth; the sides are paler, the pale tint being continued to the margin. The tentacular filaments are about forty in number; they are

Fig. 23.—Part of the branchial sac of *Ascidia Morei*, highly magnified.

closely set, colourless, hyaline, and are dotted with opaque white. The branchial tubercle (Pl. XIV, fig. 3) is well developed, angular at the sides, lozenge-shaped, and the convolutions are rather peculiar.

The primary blood-vessels of the branchial sac are very regularly disposed and do not vary much in size. The secondary blood-channels are peculiar; they are exceedingly wide and irregular, the stomata being short, elliptical, and irregular in size. They rarely reach the whole width of the space between the primary vessels, and are not infrequently quite minute; the result is that the whole of the tissue has the appearance of a perforated membrane which is

minutely and rather deeply plicated. The rods are strong, with the papillary membrane rather contracted, but having the upper border, at its junction with the rod, abruptly enlarged so as to assume the appearance of an obtuse tubercle.

The greater portion of the alimentary canal is covered with vesicular matter, obscuring the organ; consequently the male vesicles could not be observed. The ovary (Pl. XV, fig. 7), as well as the oviduct, contained white eggs.

This species is named after its discoverer, Mr. A. G. More, of Dublin. Its nearest allies are *Ascidia scabra* and *A. sordida*.]

23. **Ascidia scabra** Müller.

(Pl. XV, figs. 1–7; Pl. XVIII, fig. 7; Pl. XIX, fig. 10; and fig. 1 in text.)

Ascidia scabra and *aspersa* Müller Zool. Dan. Prod. [1776], p. 225, no. 2726, 2728, and Zool. Danica, II [1788], p. 33, pl. lxv, f. 2, 3; [Thompson in Ann. Nat. Hist. (1) V (1840), p. 94;] Forbes and Hanley Brit. Moll. I [1848], pp. 33, 35; Thompson Nat. Hist. Ireland, IV [1856], p. 360; [McIntosh Proc. R. Soc. Edinb. V (1866), p. 605].

Ascidia scabra Forbes and Hanley Brit. Moll. I [1848], p. 33, pl. C, f. 3; [Norman Rep. Brit. Assoc. 1868 (1869), p. 302].

[*Ascidia scabra* ? Forbes Rep. Brit. Assoc. 1850 (1851), p. 242.

Ascidia aspersa Carus in Proc. Ashmol. Soc. I (1851), p. 266; ? Alder Rep. Brit. Assoc. 1866 (1867), p. 207.]

Body suborbicular or ovate, a little compressed, generally adhering largely by the side; but rather irregular in outline and area of attachment. *Apertures* sublateral, not far apart, forming short, broad, echinated, reddish tubes. Test tough, transparent, colourless, more or less tuberculated, especially towards the apertures; sometimes nearly smooth. *Mantle* semi-

transparent, yellowish white, more or less blotched with red and with minute opaque white spots; a large white spot between the apertures on the ganglionic region. *Tentacular filaments* numerous, long, variable in size, devoid of opaque white. *Branchial sac* spotted with red, minutely plicated, with the stomata elliptical; the papillary membranes ample, with the thickened margin narrow and projecting very slightly from the front of the longitudinal rods. *Oral lamina* well developed, ribbed; the left oral appendages, four or five simple, diagonal, narrow ridges.

Length from three-quarters of an inch to an inch and a quarter.

Hab.—On the under-side of stones, on shells and fuci, in shallowish water, sometimes between tide-marks.

England.—Not uncommon on the south and west coasts. Lulworth Cove, Dorset (*Jeffreys*). Plymouth, Devon (*Bate*). [Scilly Isles (*Carus*, 1850).] Isle of Man (*Alder*).

Wales.—Tenby, Pembroke; and Menai Straits, Carnarvon (*Alder*).

Scotland.—West coast (*Forbes*). [Hebrides (*Alder*, 1866). North Uist, Outer Hebrides (*McIntosh*, 1865). Island of Housay, Out Skerries, West Voe, Shetland (*Norman*, 1868).]

Ireland.—[Irish Sea, not rare (*Forbes*).] Strangford Lough, Down (*Thompson* [and *Norman*].) [Belfast Lough, Antrim (*Thompson*, 1840). Clew Bay, Mayo (*Thompson*, 1856).] Killery Bay, Galway, on the fronds of *Laminaria* (*Thompson*, *Ball*, and *Forbes*).

First record.—[Thompson, 1840.]

A. scabra is considerably depressed and the test (Pl. XV, f. 1) is rather thick and firm, and is generally attached by the whole side, though somewhat variable in this respect. It varies greatly in the degree of tuberculation, some individuals being strongly tubercular or aculeated over the entire surface, while in

others the tubercles are almost wholly confined to the tubes, where they are always most numerous, and frequently compound.

The mantle (Pl. XV, fig. 2) is delicate and is usually tinged with yellow, sometimes with a rosy hue, and is blotched with red on both sides; the blotches, which are rounded, become confluent on the tubes. The freckling of opaque white is sometimes confined to the track of the alimentary tube, and is accumulated in a large spot in the ganglionic region; in some specimens nearly the whole mantle is suffused with red.

The branchial sac (Pl. XVIII, fig. 7) extends to the bottom of the test, and has the minute plications well defined; the primary vessels are regularly disposed; the stomata are elliptical, shorter than usual, and frequently do not extend the whole width of the space between the primary vessels, and they are occasionally irregularly disposed; the papillary membranes are ample, with the thickened free margin narrow, and scarcely if at all projecting beyond the longitudinal bar. The longitudinal bars are delicate, with the suspended membrane rather wide. The oral lamina (Pl. XIX, fig. 10) is broad, with the right side strongly ribbed and the margin entire; it terminates at the bottom of the branchial sac immediately below the mouth, where it is produced into an inconspicuous lobe that appears to overhang the oral orifice. On the left side of the mouth there are four or five, simple, obscure, diagonal, ridges—the left oral appendages. The tentacular filaments are numerous, varying from 36 to nearly 50; they are variable in size, are long and slender, and devoid of opaque white. The branchial tubercle is a simple loop, open in front, and occasionally with the extremities turned a little inwards.

The ovary is a beautifully-branched, tubular organ, ramifying over the left side of the intestinal loop: the male organ is inconspicuous. The loop of the alimentary tube forms a regular oval mass which lies towards the dorsal region and extends from the bottom

of the pallial sac to nearly half way up; the rectal portion diverges to the base of the excurrent tube, where it terminates in a wide anal orifice, with a smooth reflected margin. The left side of the stomach is thickly covered with vesicular matter which is extended over the intestinal loop, and this, as well as the stomach and œsophagus, is yellowish, blotched, and marked with red; the rectum is hyaline.

We have followed the opinion of Professor Sars in considering the *Ascidia aspersa* of Müller to be the young of this species, which is extremely variable both in form and colour. Specimens with the mantle blotched with red are much more common than those which have it all of that colour.

Ascidia scabra in some of its forms bears a great resemblance to *A. sordida*, whose place it seems to take on the south-west of Great Britain, though generally found in shallower water, and sometimes between tide-marks. It is smaller, more largely attached, and more tuberculated than *A. sordida*, and has the orifices situated rather more to one side; and moreover, while the latter belongs to the division with the branchial sac papillose, *A. scabra* has it non-papillose. Its closest allies, however, are [*A. Morei*,] *A. affinis*, and *A. Normani*; but from each of these it has many distinguishing features.

[Var. **albida** *Nobis.*] (Pl. XV, figs. 3 and 4.)

[*Ascidia albida* Alder and Hancock in Trans. Tyneside N. F. Club, I (1848), p. 200.]

A colourless variety not infrequently occurs, entirely devoid of blotches and spots, except those of opaque white. This pretty variety might easily be taken to be a distinct species; but it agrees in all essential characters with *A. scabra*.

England.—Cullercoats, Northumberland (*Alder & Hancock*). [Falmouth, Cornwall (*Cocks*, 1849).]

[Var. **echinata** *var. nov.*] (Pl. XV, figs. 5–7.)

Strongly echinated, much depressed, and adhering for its whole length; the sides of the test spreading in a flat disc.

Length half an inch.

Scotland. — Lamlash Bay, Arran (*Stevenson & Carpenter*).

[Var. **lævis** *var. nov.*]

Orbicular, adhering largely by the side. Test smooth or wrinkled, with the apertures very large and strongly echinated.

Length three quarters of an inch.

Channel Islands.—Guernsey (*Alder*).

24. **Ascidia Normani** Alder and Hancock.

(Pl. IV, figs. 3 and 4; Pl. XVIII, fig. 8; Pl. XIX, fig. 11; Pl. XX, fig. 9.)

[*Ascidia Normani* Alder and Hancock in Ann. Nat. Hist. (4) VI (1870), p. 361.]

Body elongated, pretty-regularly oval, white, delicately tinged with rosy flesh-colour, attached by the side of the base, transparent, strongly echinated, particularly towards the base and apertures, where the spines are usually compound. *Apertures* of a rose-colour, wide, produced, strongly ribbed and echinated longitudinally; the branchial being terminal, the anal about a third down the ventral margin; ocelli small, inconspicuous. *Test* thin, transparent, white, or only slightly tinged with pale flesh-colour, covered with simple and compound spines, strongest towards the apertures and base. *Mantle* delicate, of a pale buff flesh-colour, or almost colourless, the tubes well produced, and of a rosy colour. *Tentacular filaments* rather long, white, wide at the base, distant, alternately large and small, not very numerous. *Branchial sac* minutely plicated; stomata long; thickened margin of

the papillary membranes delicate, very slightly produced. *Oral lamina* well developed, ribbed, margin entire; the left oral appendages five or six, denticulated, leaf-like, placed diagonally.

Length sometimes nearly three inches but usually under two inches.

Hab.—Between tide-marks.

Scotland.—Firth of Clyde (*Robertson*).

Ireland.—Strangford Lough, Down (*Norman*). Birterbuy Bay, Connemara, Galway, dredged (*More*).

First record.—Hancock, 1870; *coll.* Norman [1869].

This is a very beautiful species, the test (Pl. IV, fig. 3) being of a clear white, delicately tinged with rosy flesh-colour, and when strongly echinated, as it most frequently is, it has a fretted or frosted appearance. It is usually attached to Fuci for a small space by the side of the base. The external spines are to a great extent compound.

The mantle (Pl. IV, fig. 4) is delicate and transparent with a blush of yellow flesh-colour, and the muscular fibres are slender, and sparsely distributed; there is no opaque white on either side, except in the region of the stomach which in some specimens is covered with a minute freckling of white or yellow matter. The tubes are wide, and of a rosy hue, particularly at the margin which is occasionally encircled with rose-colour: the excurrent tube is quite one-third down the side; the branchial is terminal.

The branchial sac (Pl. XVIII, fig. 8) has a few scattered spots of opaque white which are mostly in connection with the suspending vessels; it is minutely plicated; the primary vessels are pretty-regularly alternately large and small, but do not vary much in size. The ciliated discs are large and oval; they are placed on the sides of the vessels and are in pairs between the longitudinal bars; the discs of each pair are separated a little and diverge forward or towards the oral lamina. The stomata are long, with the ex-

tremities irregularly pointed or rounded. The longitudinal bars are well elevated, rather delicate, but rigid, with the suspended membrane wide; the papillary membranes are well developed, with the thickened margin rather narrow and not projecting so as to form a papillary point. The oral lamina (Pl. XIX, fig. 11) is wide, strongly ribbed on the right side and with the margin entire; it tapers gradually as it approaches the mouth, which is not quite at the bottom of the branchial sac, and terminates in a fine point a little below it. The left oral appendages are very characteristic; they are from 6 to 9 in number and are in the form of pectinated, diagonal laminæ; they vary somewhat in form, being either a little elongated and attenuated at the ends, or short and more or less suddenly produced; and the number of the points varies from one to four. The branchial tubercle (Pl. XX, fig. 9) is large and strongly involuted; it is shield-shaped, pointed below, wide and angulated at the sides above. There are from 25 to 30 tentacular filaments; they are well developed, rather long and attenuated above, with the base wide and blotched with opaque white, and they are placed a little apart and are alternately large and small.

The intestinal loop forms an irregular oval mass placed near the posterior extremity of the body and towards the dorsal margin; it reaches about half way up the mantle; the rectum diverges slightly and terminates at the atrium a little in advance of the loop; the anal margin is narrow, smooth, and reflected; the œsophagus rather long. The greater portion of the alimentary tube is of a delicate buff colour, and the right side of the stomach is usually covered with a dense, minute freckling of opaque white or yellow matter; the coating of vesicular matter is thin and the vesicles are minute and inconspicuous.

The ovary is a tubular, branched organ confined to the left side of the intestinal loop; the extremities of the branches, however, pass round the margins of the

loop and are seen at the right side; the ramifications are disposed in an irregular radiating manner, and are spread over the whole of the looped portion of the intestine. The male cæca are small and appear at both sides of the intestine, but are most conspicuously displayed at the centre of the right side of the intestinal loop.

The species is closely related to *A. scabra*, but is distinguished at first sight by its greater size, its rougher and more spinous test, and by its peculiarly delicate colouring; the mode of attachment, too, is different, and so are many of the minor points of detail. But the best distinguishing feature is to be found in the left oral appendages, which, in this species, are large and denticulated, while in *A. scabra* they are simple and very narrow.

[Var. **resplendens** *var. nov.*]

A brilliantly-coloured variety of this species occurs at Polperro, Cornwall. This beautiful variety might readily be mistaken for a distinct species did it not agree in every essential character with the type form. The mantle is of a clear yellowish colour, with the centre portion of the left side irregularly blotched with brilliant carmine. The blotches are usually more or less blended and occasionally are entirely fused, so as to produce a uniform patch of that colour. The tubes are also streaked longitudinally with carmine, though not always with much uniformity. The right side of the mantle is paler in hue and is entirely devoid of blotches or spots. The test is exceedingly rough and spinous, and, though white, is sufficiently transparent to exhibit the brilliant pallial colouring beneath. Like the normal form it is attached to *Fuci* diagonally by the side of the base, but sometimes rather extensively.

We have much pleasure in dedicating this species to our friend the Rev. A. M. Norman, to whom we are

indebted for a great number of new forms of both the simple and compound Tunicata.

25. **Ascidia affinis** Alder & Hancock.

(Pl. XV, figs. 8 and 9; Pl. XVIII, fig. 9; Pl. XIX, fig. 12; and fig. 3 in text.)

[*Ascidia affinis* Alder & Hancock in Ann. Nat. Hist. (4), VI (1870), p. 361.]

Body elongated, ovate, tapering upwards, semi-transparent, dirty greenish white; surface smooth or only slightly wrinkled, echinated and somewhat rugose towards the base and apertures. *Apertures* prominent, large, tubular, longitudinally ridged, rugose or echinated; the branchial terminal, the anal a little way down the ventral margin. *Test* semi-transparent, thin, cartilaginous, of an obscure, pale, soiled greenish white, smooth above and slightly roughened or echinated towards the base and tubes. *Mantle* pale olive-brown, almost colourless and transparent at the tubes, which are well produced, wide, and strongly ribbed longitudinally, both being directed upwards. *Tentacular filaments* numerous, moderately stout, alternately large and small. *Branchial sac* minutely plicated, papillary membrane with the free margin much thickened, but very slightly produced. *Oral lamina* wide, smooth, or only slightly ribbed at the base, margin entire; the left oral appendages seven or eight, large, triangular, denticulated, leaflets.

Length upwards of two inches.

Hab.—Shallow water.

England.—Roach river, Essex (*Baird*). Isle of Wight, dredged in an oyster-bed (*Jeffreys*).

First record.—Hancock, 1870; *coll.* Baird [1865 or earlier].

This species was obtained in great abundance by Dr. Baird when examining the state of Roach River, Essex, to report on its suitableness for the maintenance

of oyster fisheries. The specimens have usually a soiled appearance, are much infested by parasitic zoophytes, and are generally united at the base into clusters, the base being considerably prolonged into a sort of irregular, flat pedicle.

The test (Pl. XV, fig. 8) is rather thin and devoid of the echinations common to the group to which the species belongs, except towards the tubes which are roughened and spinous.

The mantle is well supplied with interwoven muscular fibres, the marginal and transverse ones predominating, and is of a pale brownish colour when preserved in spirit; the tubes are wide, well produced, and strongly folded longitudinally.

The branchial sac (Pl. XVIII, fig. 9) is minutely plicated and considerably elongated, with the mouth opening into it near to the bottom; the primary vessels are pretty-regularly disposed, and do not vary greatly in size; and the ciliated discs which they bear are large, ovate, and placed in pairs between the longitudinal bars; the latter are stout, not much elevated, with the suspended membrane wide; the papillary membranes are moderately developed and have the free margins much thickened and projecting very slightly beyond the rods like short truncate papillæ, one at each primary vessel.

The oral lamina (Pl. XIX, fig. 12) is wide, and for the greater part smooth, the ribs being confined to the base, and it terminates rather abruptly at the right side of the mouth; the margin is entire. The left oral appendages are 7 or 8 in number; they are well-developed, pectinated, triangular leaflets placed diagonally and each having from one to three points or teeth. The branchial tubercle (Pl. XX, fig. 10) is large and transversely oval; it is much convoluted and has the inferior margin indented. There are between 30 and 40 tentacular filaments; they are alternately large and small, and are not crowded; their bases are a little widened and marked with opaque white.

The alimentary tube is wide, and fills the lower two-thirds of the pallial sac; it is closely folded upon itself, and the rectal portion rises up perpendicularly to the atrium; the anal margin is smooth, narrow, and reflected. The vesicular matter coating the tube is inconspicuous, the nuclei, however, give to much of the surface a minute freckling; the vesicles themselves are quite small.

The ovary is composed of branched radiating tubes spread over the right side of the upper portion of the intestinal loop. A few of the extremities of the branches pass round the margin of the loop and appear at the left side. The male cæca are seen at both sides of this portion of the digestive tube, but are most conspicuous on the right side; they are small, clustered, and somewhat lobed.

At first sight *Ascidia affinis* has considerable resemblance to *A. sordida*, and the mode of aggregation into groups is very similar in both species; the colour, however, is different, and the deficiency of branchial papillæ in the former shows that its alliance is with *A. scabra* and its associates. And of these it seems most nearly related to *A. Normani*; it is distinguished, however, from that species not only by its colour, and comparative absence of echinations, which are almost entirely confined to the tubes, but by numerous other points of detail, amongst which may be mentioned the form of the left oral appendages, and the great thickness of the free margin of the papillary membranes.

26. **Ascidia pustulosa** Alder.

(Pl. XVI, figs. 1–3; Pl. XVIII, fig. 10.)

Ascidia pustulosa Alder in Ann. Nat. Hist. (3) XI [1863], p. 154.

Body ovate, rugose, horn-coloured, adhering towards the base. *Apertures* sessile, strongly tuberculated or echinated, reddish, the branchial terminal, the anal

nearly one-third down the side. *Test* rather thick, semi-transparent, coriaceous, covered with irregular-sized, warty, or pustulose tubercles, principally on the upper or left side; these generally bear lesser tubercles or echinations on their surface; the lower or recumbent side is nearly smooth. *Mantle* yellowish, blotched with red, especially towards the apertures, and sprinkled with opaque white. *Tentacular filaments* few and stout. *Branchial sac* with rather small papillæ. *Oral lamina* wide, smooth, with the right side ribbed.

Length about three inches.

Hab.—Deep water?

England.—Fowey Harbour, Cornwall, dredged (*Alder*).

Scotland.—Firth of Clyde [Lamlash Bay?] (*Allman*).

First record.—Alder, 1863 [; coll. 1847].

This species is readily distinguished from *A. mentula* by the pustulose tubercles of its test (Pl. XVI, fig. 1) as well as by its more ovate form; in these respects it approaches somewhat to *A. aculeata*, but it is of much larger size, less echinated, and of a different colour. It has only yet been found in the localities mentioned, and appears to be rare.

The mantle (Pl. XVI, fig. 2) is well supplied with muscles which are not arranged with much regularity, except at the margins from which they extend at right angles in parallel order.

The branchial sac (Pl. XVI, fig. 3, and Pl. XVIII, fig. 10) is minutely plicated, the plicæ being deeper than usual, and the meshes of the secondary vessels are rather large. The primary vessels vary in size and have a wide membrane along their sides, overlying the undulations on the inner surface, so that a slight longitudinal contraction of the respiratory web would bring their margins together and prevent or regulate the egress of the water contained in the branchial sac. There are eleven or twelve well-developed tentacular filaments, mostly with one or two smaller ones between

them, and the branchial tubercle is large with the loop placed transversely opening towards the ventral margin: the extremities are turned forwards and backwards. The oral lamina is wide, with distant ribs or pectinations on the right side, the other side seems to be smooth, though the pectinations shine through. The longitudinal bars are rather delicate, and are much elevated above the general surface; the membrane beneath is narrow, and there is one bar to each plication. The papillary membrane is ample and has the free margin much thickened and arched, and, projecting a little in front of the bar, assumes the form of a short obtuse papilla.

The ovary is a large dendritic organ spread over the left side of the visceral mass, the branches being stout and radiating: the testis is composed of a vast number of minute cæca which appear on both sides of the alimentary tube.

27. **Ascidia elliptica** Alder & Hancock.

(Pl. XVI, figs. 4–7; Pl. XVIII, fig. 11.)

Ascidia prunum [Jameson in Mem. Wernerian Soc. I (1811), p. 557; Pennant Brit. Zool. IV (1812), p. 100; Stewart Elem. Nat. Hist. I (1817), p. 391; Coldstream in Edinb. new Philos. Journ. XIV (1830), p. 239; Thompson in Ann. Nat. Hist. (1) V (1840), p. 94;] Forbes and Hanley Brit. Moll. I [1848], p. 34; [Norman Zoologist, XV (1857), p. 5708].

Pirena prunum Fleming Brit. Anim. [1828], p. 468.

Ascidia elliptica Alder and Hancock in Trans. Tyneside N.F. Club, I [1848], p. 201; Forbes and Hanley Brit. Moll. II [1849], p. 374; [Norman in Rep. Brit. Assoc. 1868 (1869), p. 302].

Ascidia prunum ? Thompson Nat Hist. Ireland, IV [1856], p. 359.

[Non *Ascidia prunum* Müller Zool. Danica (1788).]

Body elliptical, a little convex on the upper side and flat beneath, of a dull, sub-opaque brownish or yellowish white in old specimens, more transparent

when young, attached throughout its whole length. *Apertures*, branchial terminal, papillose, very little elevated, and divided into eight tubercular segments; anal situated a little below the branchial, rather prominent, with six tubercles. Ocelli rather inconspicuous. *Test* tough, sub-opaque, transparent when young, slightly tuberculated towards the apertures. *Mantle* opaque, white or flesh-coloured, with a few red spots between the apertures. *Tentacular filaments* rather long. *Branchial sac* with small primary, but no intermediate papillæ. *Oral lamina* strongly ribbed on the right side.

Length three quarters of an inch.

Hab.—On the under-side of stones at low water-mark. Common on most parts of our coast (*Forbes*).

England.—[Bristol Channel (*Forbes*).] Cullercoats, Northumb. (*Alder*). [Isle of Man (*Forbes*).]

Scotland.—[East and west coast (*Forbes*). Leith shore, Firth of Forth (*Jameson*, 1811).] Firth of Clyde (*Norman*). [Hebrides (*Forbes*, 1850). Allans, Cumbrae (*Norman*, 1857).] Shetland (*Forbes*). [(Lerwick, Shetland Isles, 1861 (*Norman*, 1868).]

Ireland.—[Strangford Lough, Down; and Belfast Lough, Antrim, dredged (*Thompson*, 1840).]

First record.—Alder and Hancock, 1848 [(Jameson, 1811, as *Ascidia prunum*)].

The test (Pl. XVI, fig. 4) appears to contain but few blood-channels; at least not many were observed.

The mantle (Pl. XVI, fig. 5) is well supplied with muscular fibres, which, in the centre, are loosely woven in various directions; but around the margin there is a broad belt of parallel fibres which converge towards the centre in pretty-regular order.

The branchial sac (Pl. XVI, fig. 6 and 7; Pl. XVIII, fig. 11) is rather delicate, and is minutely plicated as it is in most species of the genus, only here the plicæ are wider than usual. The primary vessels are a little variable in size, and the secondary rather long with

the stomata rather large. The longitudinal bars are not very stout and are further apart than usual; and there is, pretty-regularly, one to every plait. The papillary membrane is well-developed, and has the free margin thickened and arched; and, as the thickened portion projects a little from the bar, the latter seems to be provided with small, obtuse papillæ at their intersections with the primary vessels. This, however, is only a modification or rudimentary condition of the ordinary branchial papillæ. The oral lamina has on the right side strong distinct ribs; and the branchial tubercle (Pl. XX, fig. 11), at its anterior extremity, is small and loop-formed with the points placed upwards and turned to each other. The tentacular filaments are numerous, long, slender, and variable in length, and are placed very near to the anterior margin of the branchial sac.

The ovary is situated on the left side of the looped portion of the intestine, and is composed of rather delicate branches irregularly radiating from the centre; occasionally a few ovarian branches appear at the opposite side of the alimentary tube. The testicular cœca are principally on the right side of the intestine.

Professor Forbes has referred this species to the *A. prunum* of Müller, but we think erroneously. The *A. prunum* is described as lax, hyaline, and very pellucid, free or only slightly attached, dwelling in mud. This species has the test rather coriaceous, and is always firmly attached to stones throughout its whole length.

28. **Ascidia pellucida** Alder & Hancock.

(Pl. XVI, figs. 8 and 9; Pl. XVIII, fig. 12.)

Ascidia pellucida Alder and Hancock in Trans. Tyneside N.F. Club, I [1848], p. 202; Forbes and Hanley Brit. Moll. II [1849], p. 374.

Body irregularly ovate or subtriangular, hyaline, very much depressed, and attached by a thin, broadly-

extended disc. *Branchial aperture* terminal, wide and tubular; anal on a short tube a little way down the side, curving upwards; ocelli conspicuous, red. *Test* smooth, coriaceous, and perfectly transparent. *Mantle* small in proportion to the test, yellowish white, inclined to red on the lower parts.

Length half an inch.

Hab.—Under stones within tide-marks.

England.—Cullercoats, Northumb., rare (*Hancock*). [Falmouth, Cornwall (*Cocks*, 1849).]

Wales.—Menai Straits (*Alder*).

Ireland.—Killinny, Galway (*Thompson*).

First record.—Alder and Hancock, 1848.

The vascular ramifications of the test (Pl. XVI, fig. 8) are not very conspicuous; and the mantle is delicate and only feebly supplied with muscular fibres.

The branchial sac (Pl. XVIII, fig. 12) is rather wide, but does not reach to the lower border of the visceral mass; it is simple, not undulated or plicated; the primary vessels are pretty equal in size, and are placed rather near to each other; consequently the stomata are shorter than usual, and have the extremities rounded. The longitudinal bars do not bear papillæ; but in their place, at the intersection, there is a stoutish nodule or boss, which gives support to an almost obsolete papillary membrane. The oral lamina, which is not particularly wide, has the right side ribbed; and the branchial tubercle in front of it is a simple loop open above. The tentacular filaments are numerous, long, and slender, but vary in length; they are placed close together in a single line.

A. pellucida is a very distinct species, and is readily determined both by its external and internal characters. The ovate or subtriangular form, the shortness of the branchial sac, with the simple structure of the aerating surface, and the deficiency of papillæ on the longitudinal bars, at once distinguish it.

29. (?) **Ascidia orbicularis** Müller.

Ascidia orbicularis Müller Zool. Danica, II [1788], p. 53, pl. lxxix, figs. 1, 2; Thomson in Ann. Nat. Hist. (1) V [1840], p. 94; Forbes and Hanley Brit. Moll. I [1848], p. 34; Thompson Nat. Hist. Ireland, IV [1856], p. 360.

Body orbicular, depressed, whitish, adhering throughout. *Apertures* nearly terminal, approximated, sessile. *Test* hyaline, transparent, spreading, having small, unequal tubercles. *Mantle* opaque white or reddish with yellow lines.

Diameter an inch.

Hab.—Shallow water, on sea-weeds.

Ireland.—Strangford Lough, Down, on *Zostera marina* (*Thompson*).

First record.—Thompson [1840].

30. (?) **Ascidia vitrea** Van Beneden.

Ascidia vitrea Van Beneden Rech. Ascidies simples, in Mém. Acad. Roy. Belg. XX [1847], p. 61, pl. iv, figs. 1–5; Forbes and Hanley Brit. Moll. I [1848], p. 34; Alder and Hancock in Trans. Tyneside N. F. Club, I [1848], p. 200; [Forbes in Rep. Brit. Assoc. 1850 (1851), p. 242; Merrifield Nat. Hist. Brighton (1860), p. 81].

Body sub-globose or ovate, a little compressed. *Apertures* terminal, placed a little apart, the branchial largest and most produced, but both short; ocelli red. *Test* thin, transparent, membranous, and colourless. *Mantle* white, with a yellow ring near the branchial aperture.

Length half an inch.

Hab.—Shallow water, on sea-weeds, &c.

England.—Cullercoats, Northumb., on small sea-weeds (*Alder*). [Brighton, Sussex (*Merrifield*, 1860). Falmouth, Cornwall (*Cocks*, 1849).]

Ireland.—Killery Bay, Galway, on an *Alcyonidium* (*Ball*, *Thompson*, and *Forbes*).

First record.—Forbes, 1848; coll. 1840.

We have been unable satisfactorily to ascertain the species which Professor Van Beneden describes under the name of *Ascidia vitrea*, and therefore give it a place here with diffidence. It is stated by Forbes in 'British Mollusca' to have been met with in Killery Bay, by Ball, Thompson, and himself, on *Alcyonidium*, in 1840. Specimens of an Ascidian on *Alcyonidium gelatinosum* in Mr. Thompson's collection are marked with this locality and date; but they appear to us to be the young of *A. sordida*. The species met with at Cullercoats and published under this name in Tyneside Club Transactions requires also to be re-examined. It is probably the young of *Corella parallelogramma*.

EXCLUDED SPECIES,

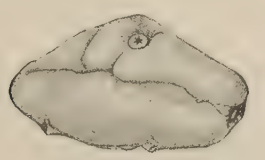
mentioned in Introduction but not given in Synonymy.

Ascidia anceps Templeton Mag. Nat. Hist. vii (1834), p. 131. Ireland.—Carrickfergus, Belfast Lough, Antrim, dredged, 1811 (*Templeton*).

A. gemina Templeton Mag. Nat. Hist. vii (1834), p. 129. Ireland.—Strangford Lough, Down (*Thompson*, 1840).

A. papilla Dalyell Edinb. new Philos. Journ. xxvi (1839), p. 153. Scotland (*Dalyell*).

A. rugosa Coldstream Edinb. New Philos. Journ. ix (1830), p. 249. Scotland.—East Lough, Tarbet, Argyllshire (*Coldstream*).



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EXPLANATIONS OF THE PLATES.

EXPLANATION OF THE LETTERING.

br. Branchial aperture.
br. s. Branchial sac.
b. t. Branchial tubercle.
en. Endostyle.
i. Intestine.
m. Mantle.
mo. Mouth.
n. g. Nerve-ganglion.
œ. Œsophagus.
od. Oviduct.
o. l. Oral lamina.
t. Test.
t. c. Tentacular collar.
tn. Tentacles.
ts. Testis.
v. Ovary.
v. t. Blood-vessels leading to test.

Plate 1

PLATE I.

Ascidia mamillata Cuv. (p. 72)

Test : natural size.

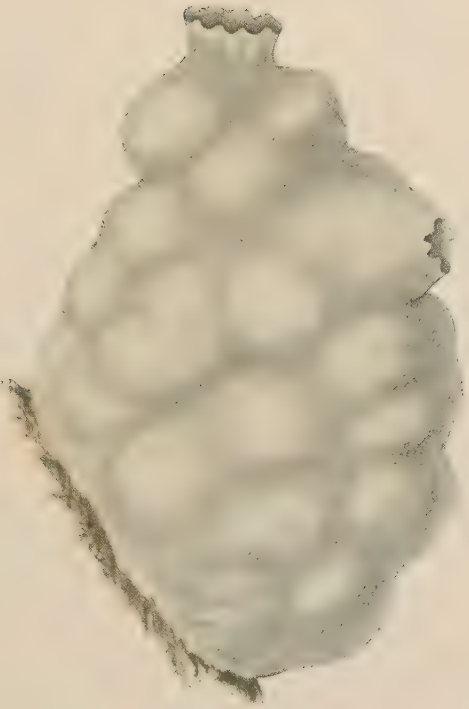
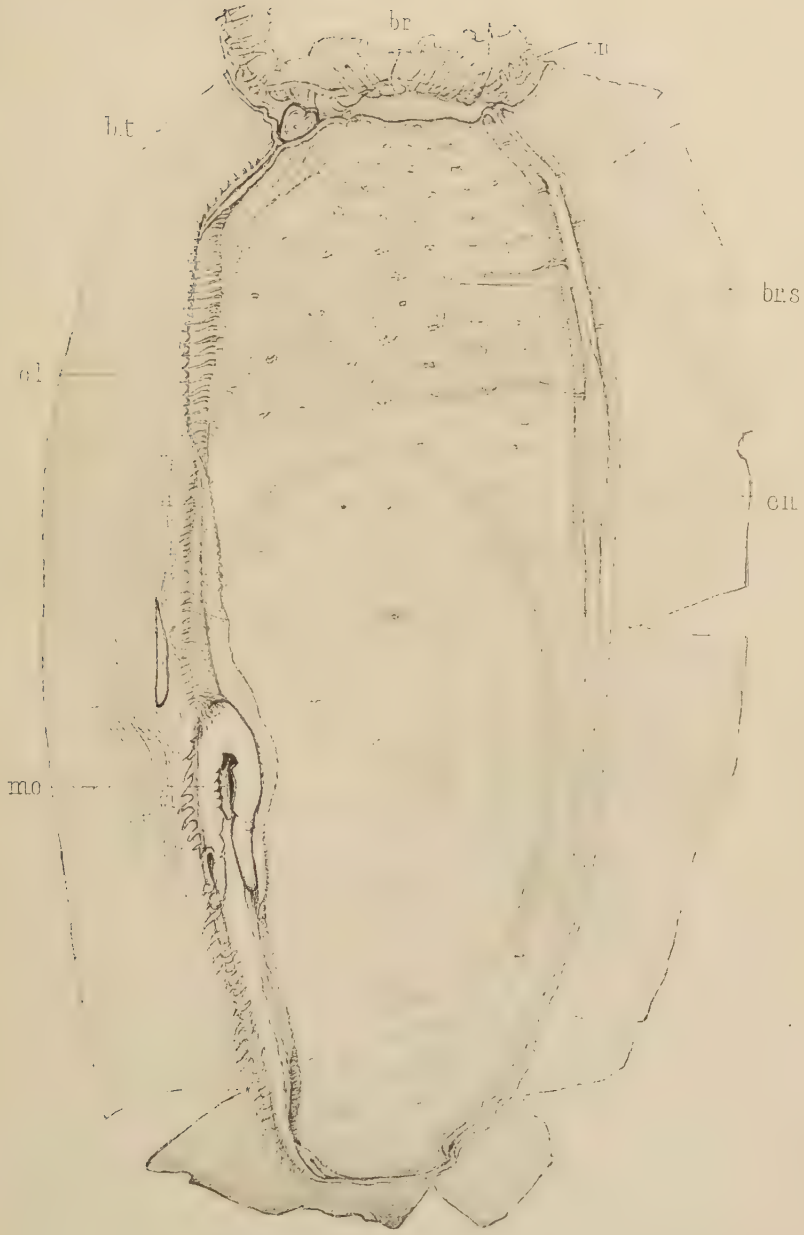


Plate 2

PLATE II.

Ascidia mentula Müll. (p. 75)

Mantle laid open (see p. 78) : about one and a half times natural size.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br.t
br.s
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cm
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Plate 3

PLATE III.

Ascidia mentula Müll. (p. 75)

Fig.

1. Aperture of branchial sac.
2. Central portion of ventral blood-channel, continued at × in fig. 3. *a*, vessel leading from mantle and appearing to open into lateral vessel at *b* (repeated above and below), and perhaps into net-work of vessels in space *c*. *d* (repeated below), vessel leading from mantle to branchial vessel *e*, and apparently opening into it.
4. Heart, with blood-channels leading from it.
5. Endostyle; anterior end.

All the figures magnified.

1
t c
b t
t n
o.l
e
2
x
c
4
en
x
5
d
c
b
a
e'
5

Plate 4

PLATE IV.

Figs.

1 and 2. *Ascidia rubicunda* Hanc. (p. 83) 1.—Test : three-fifths natural size. 2.—Mantle : four-fifths natural size. The projecting tubes on the left are blood-channels communicating with the test. The nerve-ganglion is seen about midway between the two apertures, and on the opposite side is the endostyle. In the centre are the ovary, oviduct, and intestine, seen through the transparent mantle.

3 and 4. *Ascidia Normani* A. & H. (p. 132) 3.—Test: one and a half times natural size. 4.—Mantle : natural size.

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2

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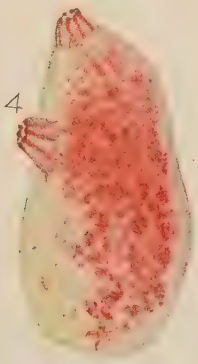
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Plate 5

PLATE V.

FIGS.

1–6. *Ascidia mollis*, A. & H. (p. 92) 1–3.—Views of test: natural size. 4.—Blood-vessels in test: magnified. 5 and 6.—Views of mantle: natural size. (2 and 5, right side; 1 and 6, left side.)

7–11. *A. mollis* var. *carnosa* var. nov. (p. 94) 7 and 8.—Views of test: natural size. 9.—Blood-vessels in test: magnified. 10 and 11.—Views of mantle: slightly enlarged. (8 and 10, right side; 7 and 11, left side.)

1

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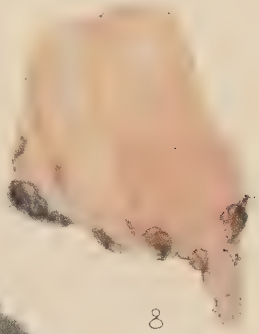

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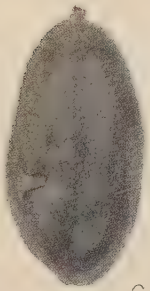

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Plate 6

PLATE VI.

Ascidia plana Hanc. (p. 94)

Mantle, showing blood-channels, &c.

Three times natural size.

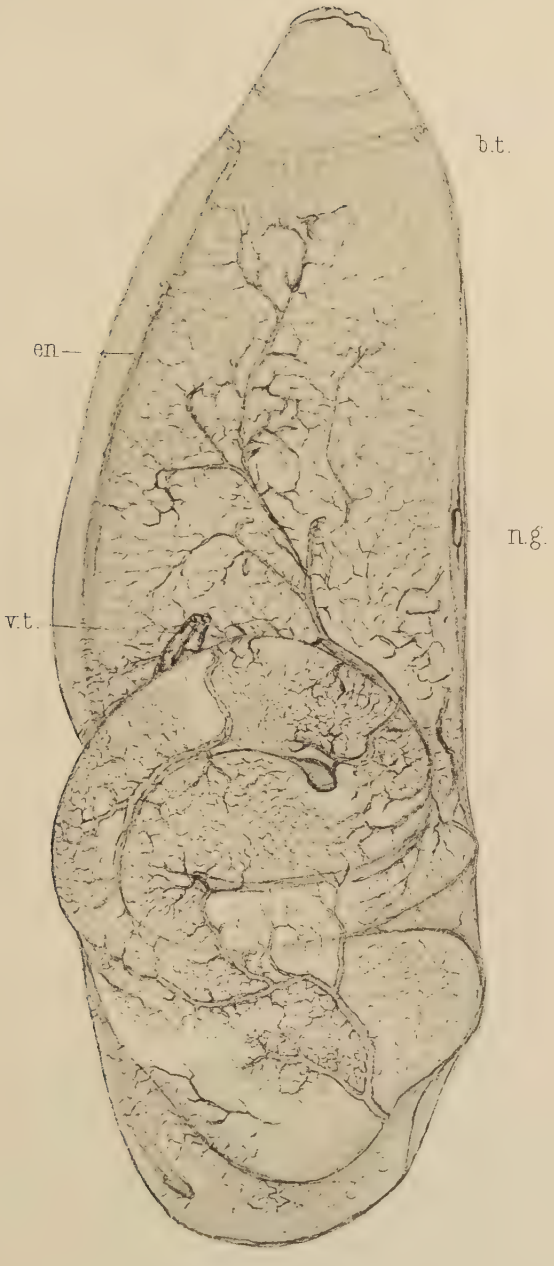
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Plate 7

PLATE VII.

Figs.

1–4. *Ascidia rudis* Alder. (p. 100) 1.—Test: natural size. 2.—Mantle: natural size. 3.—Part of branchial sac: magnified. 4.—Ocelli: highly magnified.

5. *Ascidia venosa* Müll. (p. 102) Test: natural size.

6–8. *Ascidia depressa* A. & H. (p. 111) 6.—Test: natural size. 7 and 8.—Views of mantle: natural size (7, right side; 8, left side).

9–11. *Ascidia aculeata* Alder. (p. 114) 9.—Test: natural size. 10.—Mantle: natural size. 11.—Part of branchial sac: magnified.

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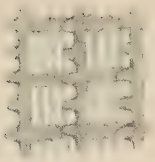

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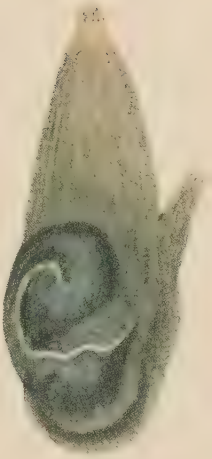

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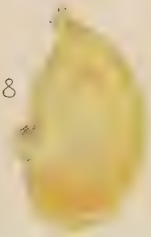

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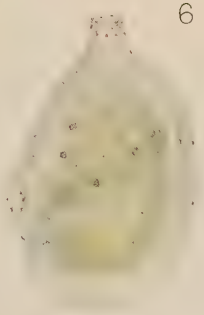

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Plate 8

PLATE VIII.

Ascidia venosa Müll. (p. 102)

Showing blood-channels in test.

Five times natural size.

Plate 9

PLATE IX.

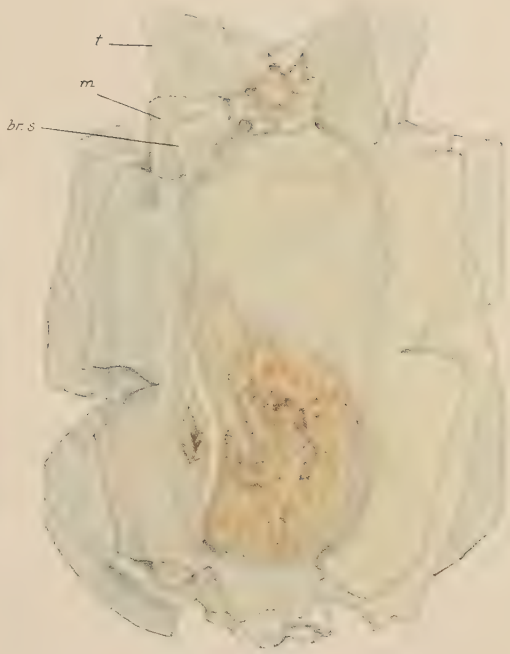
Ascidia venosa Müll. (p. 102)

Fig.

1. The mantle.
2. Test and mantle laid open. The tentacles, tentacular collar, endostyle (on right), branchial tubercle, oral lamina with gland under nerve-ganglion (opposite *br.s.*), and mouth, &c., are shown.
3. Test laid open, showing apertures of mantle, intestine, blood vessels leading to test, &c.
4. Mantle with most of branchial sac laid open. ♀, opening of female duct. ♂, opening of male duct. (The pointer from *v.t.* is carried in error across the vessel.)

About two and a half times natural size.

1



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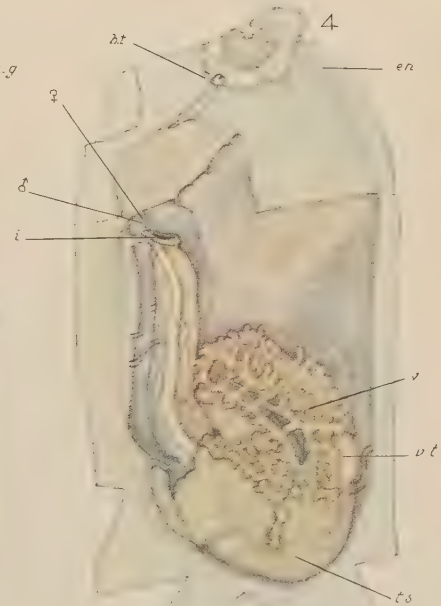


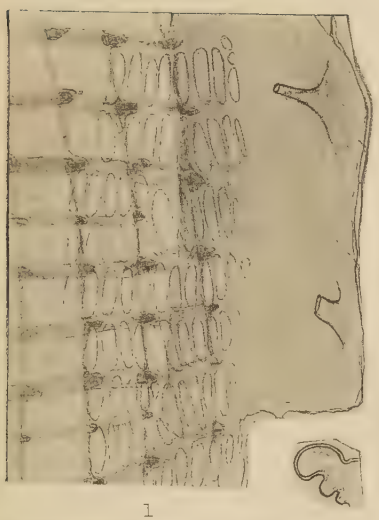
Plate 10

PLATE X.

Ascidia venosa Müll. (p. 102)

Portions of branchial sac (see pp. 41–43 and 104): much enlarged.

These figures are two-fifths the size of Mr. Hancock's drawings, being the greatest reduction made in any.



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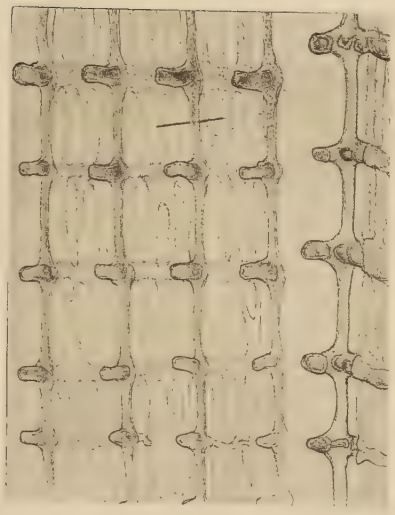

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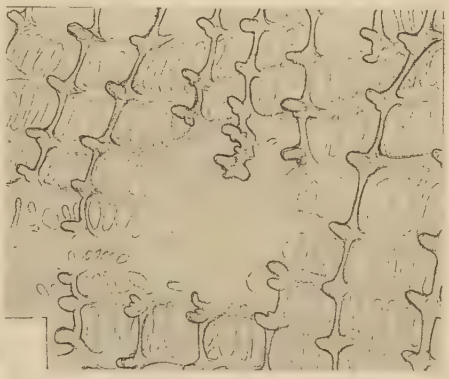

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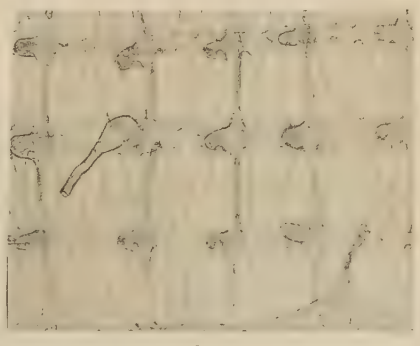

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Plate 11

PLATE XI.

Figs.

1 and 2. *Ascidia amœna* sp. nov. (p. 116) 1.—Test, with branchial aperture directed upwards: one and a half times natural size. 2.—Test of another individual, with branchial aperture directed downwards: natural size.

3–5. *Ascidia plebeia* Alder. (p. 117) 3.—Test: natural size. 4.—Part of branchial sac: magnified. 5.—Ocelli: highly magnified.

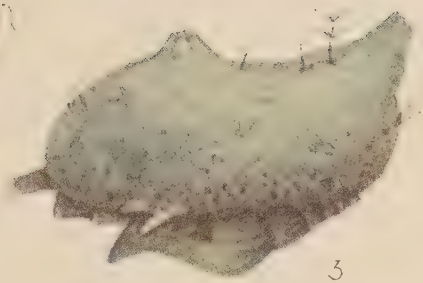
6 and 7. *Ascidia sordida* A. & H. (p. 119) 6.—Tests of two individuals: natural size. 7.—Mantle of another individual: natural size.

8 and 9. Probably a variety of *Corella parallelogramma*. Views of test: one half natural size (8, right side; 9, left side).

10. *Ascidia obliqua* Alder. (p. 124) Test: natural size.

1

5



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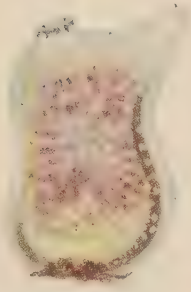

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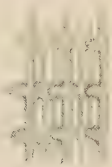

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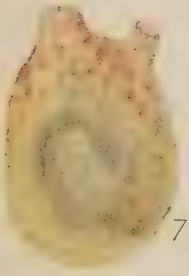

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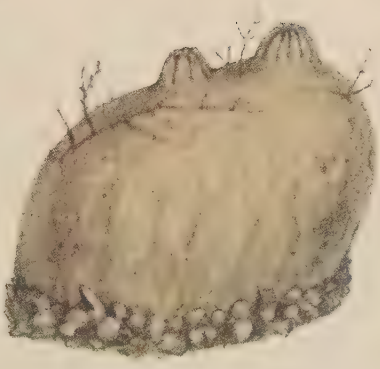

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Plate 12

PLATE XII.

Ascidia sordida A. & H. (p. 119)

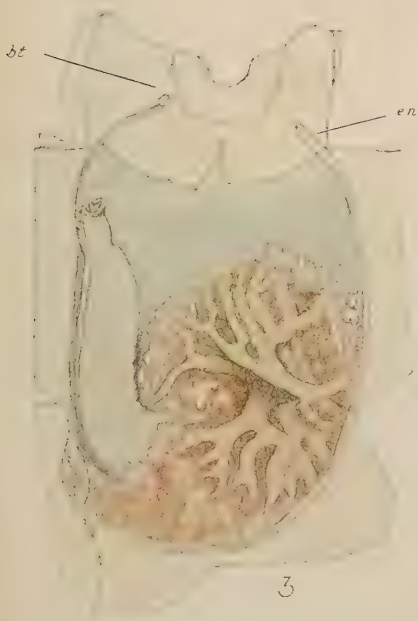
Fig.

1. Mantle. The male cæca, above blood-channel leading to test, are well shown.
2. Mantle laid open, exposing branchial sac, mouth, and oral lamina, &c.
3. Mantle and branchial sac laid open. The ovary is well shown, with the oviduct lying close to the intestine.
4. Mantle and branchial sac laid open. The nearly circular markings are the male cæca.

Twice natural size.

1

2



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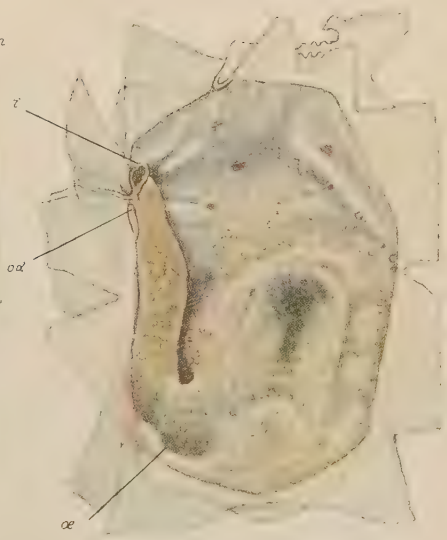


Plate 13

PLATE XIII.

Ascidia sordida A. & H. (p. 119)

Reproduction.

Figs.

1. Test and mantle laid open, showing reproductive organs —ovary in centre, male cæca on either side, and oviduct full of eggs mostly passing out in single series: about twice natural size.
2. Anal aperture, oviduct, and *vas deferens*: magnified. *Cf.* Plate XII, figs. 3 and 4.
3. Aperture of oviduct (*a*) and of *vas deferens* (*b*): more highly magnified.

4–6. Clusters of eggs: highly magnified.

7. A single ovum, showing glassy layer (*a*) and yolk (*b*): highly magnified.
8. Male cæca: magnified.

1
2
3
a
b
4
5
6
7
a
b
8
9

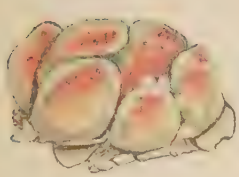
Plate 14

PLATE XIV.

Ascidia Morei sp. nov. (p. 126)

Figs.

1. A group of individuals: two-thirds natural size.
2. A single individual: enlarged one-third.
3. Branchial tubercle; two forms: highly magnified. (The colouring is not accurate.)
4. Left hand side of mantle, showing blood-vessel leading to test: three times natural size.
5. Right hand side of mantle, showing blood-vessel leading to test: three times natural size.
6. Mantle laid open, showing branchial sac, branchial tubercle, oral lamina, mouth, and endostyle: about three and a half times natural size.
7. Branchial sac laid open, showing intestine, œsophagus, ovary, oviduct, etc.: about three and a half times natural size.



1

2

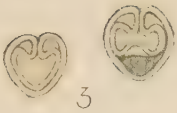


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Plate 15

PLATE XV.

Figs.

1 and 2. *Ascidia scabra* Müll. (p. 128) 1.—Test: natural size. 2.—Mantle: slightly enlarged.

3 and 4. *A. scabra* var. *albida* A. & H. (p. 131) 3.—Test: natural size. 4.—Mantle: slightly enlarged.

5–7. *A. scabra* var. *echinata* (p. 132) 5.—Test: slightly enlarged. 6 and 7.—Views of mantle of another individual: slightly enlarged.

8 and 9. *A. affinis* A. & H. (p. 136) 8.—Test: natural size. 9.—?.

1

3

2

6

8

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5

4

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Plate 16

PLATE XVI.

Figs.

1–3. *Ascidia pustulosa* Alder. (p. 138) 1.—Test : natural size. 2.—Mantle : two-thirds natural size. 3.—Part of branchial sac : magnified.

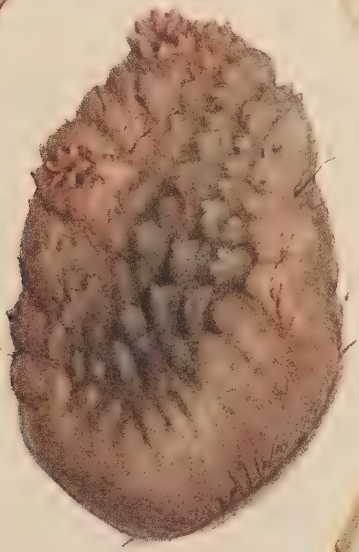
4–7. *A. elliptica* A. & H. (p. 140). 4.—Test : twice natural size. 5.—Mantle : twice natural size. 6.—Part of branchial sac : magnified. 7.—Part of the same ; side view : magnified.

8 and 9. *A. pellucida* A. & H. (p. 142) 8.—Test : twice natural size. 9.—Branchial aperture showing seven ocelli in place of the usual eight : magnified six diameters.

4

2

1



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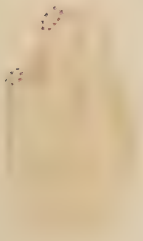

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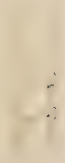

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Plate 17

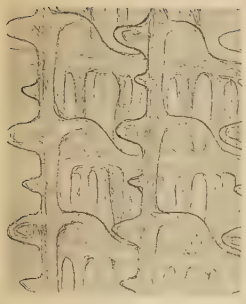
PLATE XVII.

THE BRANCHIAL SAC.

FIG.

1. *Ascidia mentula* Müll. (p. 78)
2. *A. rubicunda* Hanc. (p. 84)
3. *A. rubrotincta* Hanc. (p. 86)
4. *A. crassa* Hanc. (p. 90)
5. *A. mollis* A. & H. (p. 93)
6. *A. plana* Hanc. (p. 96)
7. *A. Alderi* Hanc. (p. 99)
8. *A. rudis* Alder (p. 101)
9. *A. producta* Hanc. (p. 106)
10. *A. inornata* Hanc. (p. 109)
11. *A. depressa* A. & H. (p. 112)
12. *A. elongata* A. & H. (p. 113)

All the figures much enlarged, but reduced in various proportions from Mr. Hancock's drawings.



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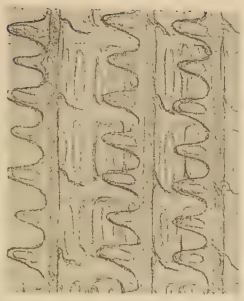

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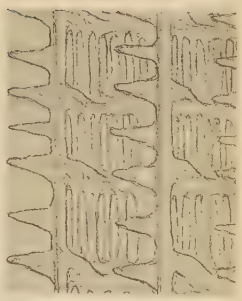

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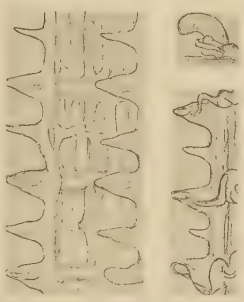

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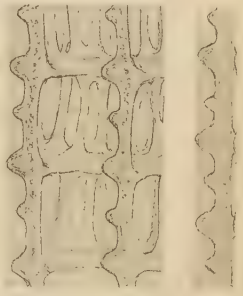

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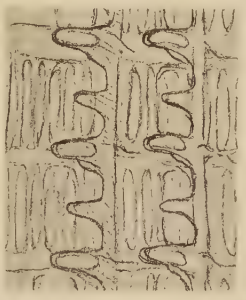

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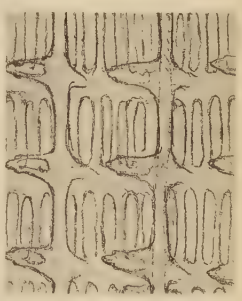

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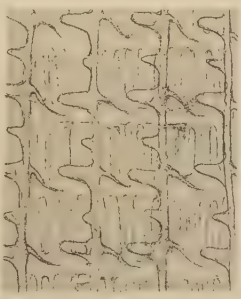

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Plate 18

PLATE XVIII.

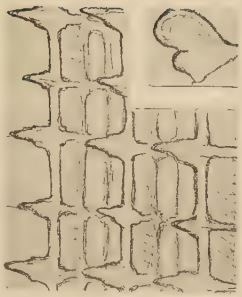
The Branchial Sac.

FIG.

1. *Ascidia aculeata* Alder. (p. 115)
2. *A. amœna* sp. nov. (p. 117)
3. *A. plebeia* Alder (p. 118)
4. *A. sordida* A. & H. (p. 121)
5. *A. canina* Müll. (p. 123)
6. *A. obliqua* Alder (p. 125)
7. *A. scabra* Müll. (p. 130)
8. *A. Normani* A. & H. (p. 133)
9. *A. affinis* A. & H. (p. 137)
10. *A. pustulosa* Alder (p. 139)
11. *A. elliptica* A. & H. (p. 141)
12. *A. pellucida* A. & H. (p. 143)

All the figures much enlarged, but reduced in various proportions from Mr. Hancock's drawings.

1



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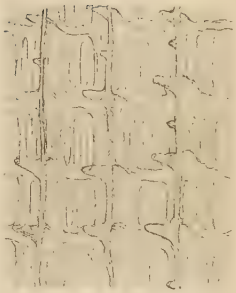

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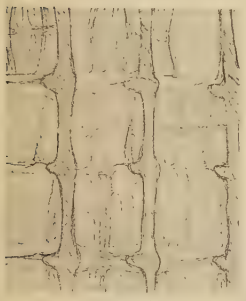

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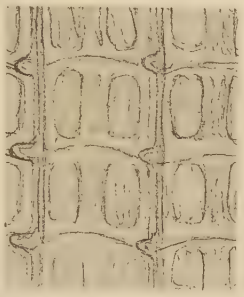

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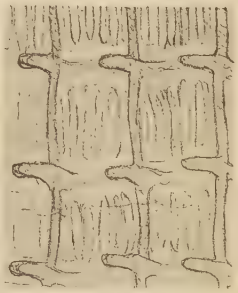

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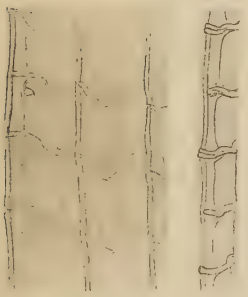

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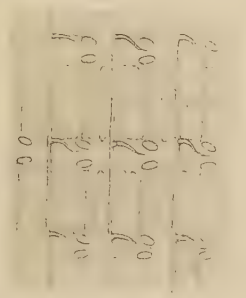

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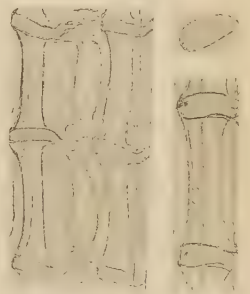

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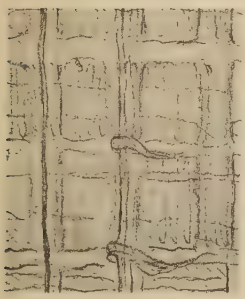

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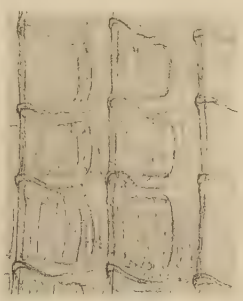

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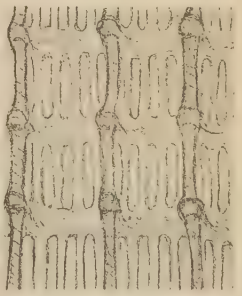

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Plate 19

PLATE XIX.

The Mouth and Oral Lamina.

FIG.

1. *Ascidia rubicunda* Hanc. (p. 84)
2. *A. rubrotincta* Hanc. (p. 87)
3. *A. crassa* Hanc. (p. 90)
4. *A. mollis* A. & H. (p. 93)
5. *A. plana* Hanc. (p. 96)
6. *A. Alderi* Hanc. (p. 99)
7. *A. producta* Hanc. (p. 106)
8. *A. depressa* A. & H. (p. 112)
9. *A. aculeata* Alder (p. 115)
10. *A. scabra* Müll. (p. 130)
11. *A. Normani* A. & H. (p. 134)
12. *A. affinis* A. & H. (p. 137)

All the figures much enlarged, but considerably reduced from Mr. Hancock's drawings.

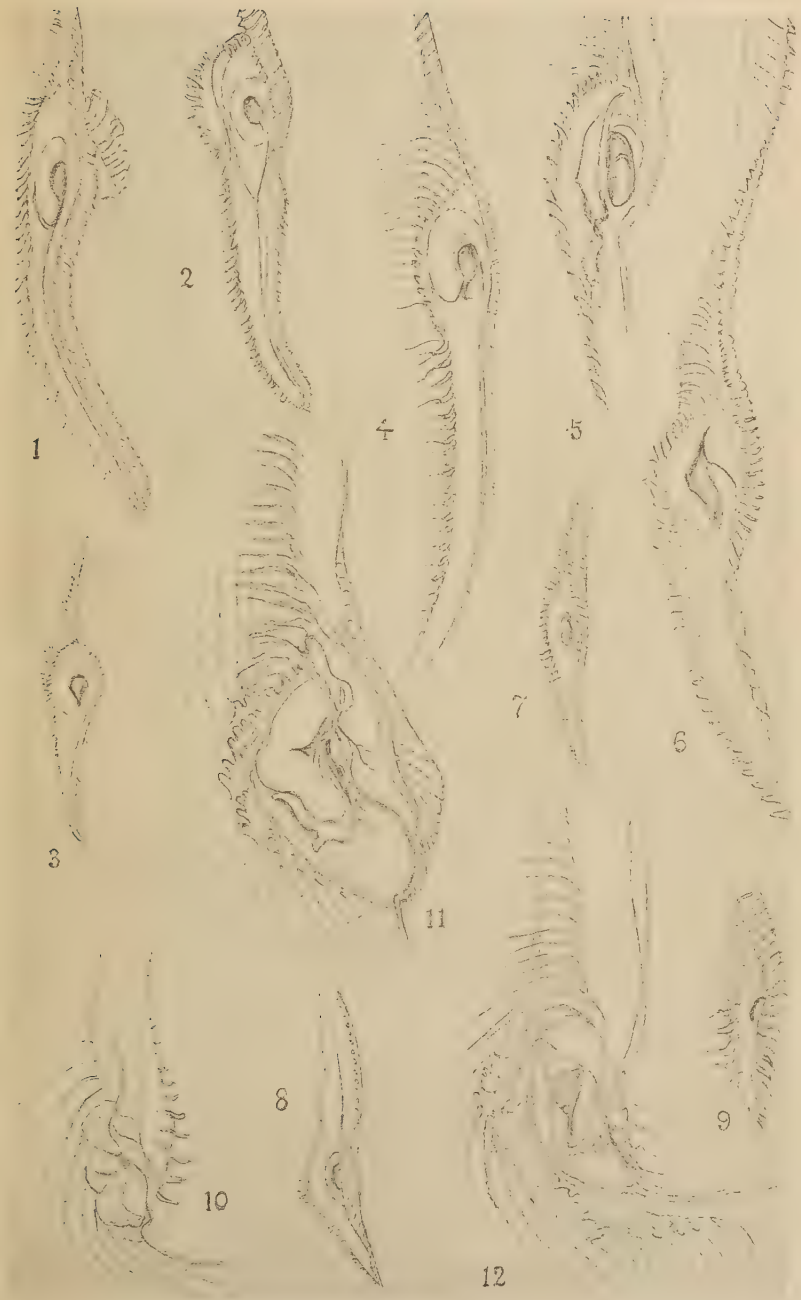
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Plate 20

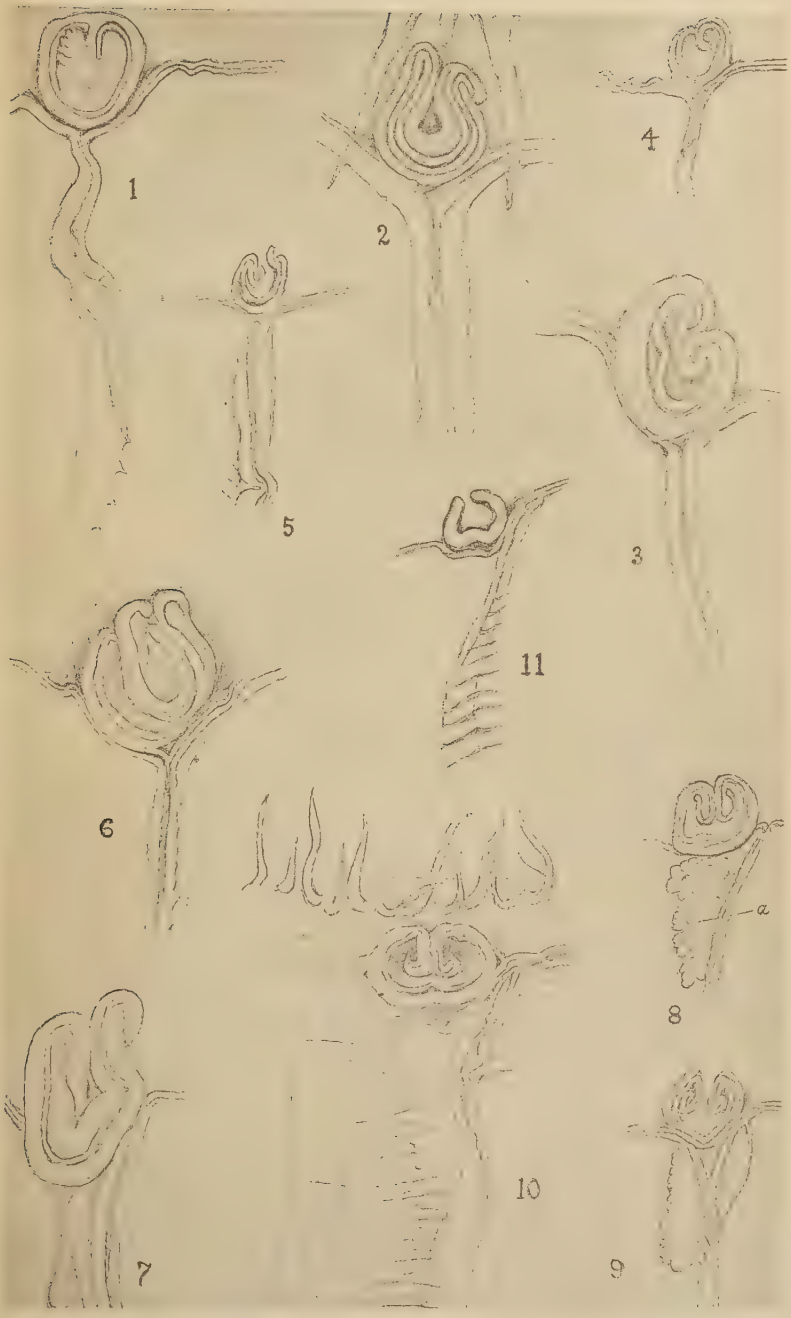
PLATE XX.

The Branchial Tubercle.

Fig.

1. *Ascidia mentula* Müll (p. 78)
2. *A. robusta* Hanc. (p. 82)
3. „ „ another form.
4. *A. rubicunda* Hanc. (p. 84)
5. *A. crassa* Hanc. (p. 91)
6. *A. plana* Hanc. (p. 96)
7. *A. sordida* A. & H. (p. 121)
8. *A. canina* Müll. (p. 124)
9. *A. Normani* A. & H. (p. 134)
10. *A. affinis* A. & H. (p. 137)
11. *A. elliptica* A & H. (p. 142)

All the figures much enlarged, but considerably reduced from Mr. Hancock's drawings.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